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Sivbritt Dumbrajs

A LEARNING COMMUNITY

TEACHERS AND STUDENTS ENGAGED IN DEVELOPING THEIR OWN LEARNING AND UNDERSTANDING

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ABSTRACT

A new curriculum planned for the Finnish schools was taken into use in 2006. Chemistry and physics were accordingly taught as separate subjects already at grades 5 and 6 in primary school. A spontaneously formed group of secondary and primary school teachers, the PLOT team, PLOT standing for Problem based Learning and Tutorship (in Swedish Problembaserat Lärande Och Tutorskap) decided some years ago to find suitable experiments for these grades. The aim was to make the experiments easy enough to be performed in ordinary classrooms without much equipment. Another important feature to consider was that the class teachers generally did not know very much physics or chemistry, which meant that the experiments should not demand deep knowledge of these subjects. Considering these conditions it was decided to make the approach problem based.

The process of gathering data and writing a text that explains data takes the form of a narrative enterprise. Narrativity cannot be considered a research method, but is an incoherent set of inquiries that have connections to narratives. It thus refers to a large number and a great variety of approaches. At the core of any narrative research is analysis of narrations or stories. Such analysis produces a new story from the

narratives in the data. This story, interpretive from original texts, is in itself fictional. In my study I produce a narrative by interpreting the narratives in the data. This study explores the experiences of the PLOT members, primary school teachers and students during the adaptation process of the new curriculum. I view my world in terms of systems. Individuals and organizations are seen as participants in a larger system. Rather than understanding organizations as mechanistic structures of tasks or people they are truly living organisms that evolve and adapt to the changing environment.

The produced material for physics and chemistry instruction in grades five and six can be considered an innovation that includes the ideas of novelty, progress or betterment, as well as the questions of empowerment and change. The primary process of adaptation is the learning process. The concept of learning emerges as constructive and can be understood as a by-product of participation in a social practice. The learning process is iterative. Learning occurs through the dialectical movement of action and reflection as learners move outward into the external world and inward into themselves. The products of one cycle become the raw material for the next cycle. Each cycle contains self-regulation, collaborative action and communication.

The original purpose of this work was to try to meet the demands posed by the new national curriculum. However, during the process the focus was shifted towards the learning process itself and school as a learning organization. At the beginning students' learning in groups, students' motivation and understanding of their own learning was seen as most important. But also the teachers who tried to implement problem based learning as a teaching method noticed that their way of thinking changed; they learned how to teach. This process, learning as an implication of working together as a team, became the most important part of my study. The teachers' experiences of the workshops they organized for primary school teachers were especially valuable considering present and future action. The different culture of primary schools when compared to secondary schools became visible. As the primary and lower secondary schools now are combined to a comprehensive school this difference in culture must be recognized.

This study has strongly influenced the work and way of thinking of the teachers in the PLOT team. It has contributed to the realization of their potential abilities as teachers, instructors and facilitators. It has also revealed difficulties in implementation of open inquiry in the science curriculum, especially in primary schools. The culture of teaching facts that prevails among primary school teachers stands in contradiction to open inquiry, according to which all starting points are meaningful to the learner and need to be used by the instructor. The PLOT method with its use of external expert knowledge has also opened the door to a deeper collaboration with the enterprise sector, especially with technological companies and organizations of education.

Teams have a central role in the knowledge creation process. They supply a shared context for interaction in which new points of view are created through dialogue. Thereby tacit knowledge becomes explicit; explicit knowledge is linked together; internalization takes place. The communication between team members and between teams has been considered as a means of developing the learning process of the organization. Knowledge is not just information, facts. It is also a dynamic human process of justifying personal belief. Knowledge, skills and performance are not static, but developmental in accordance with increasing and changing experience. Individuals in a team must be capable of adapting themselves to the changes in the demands on performance. Continuous learning is an essential aspect of team development. Learning is a way of finding meaning through new ideas and experiences. A spiral movement occurs as these are grounded in the discursive process and questioned from different perspectives. I hope that the large potential resources that exist in individuals could be allowed to develop into creative, innovative teamwork at schools. This would prepare the students for the demands of the knowledge society at the same time as their teachers would develop into learning and knowing facilitators and guides, experiencing the wonders of each new day at school.

Sivbritt Dumbrajs

GEMENSAMT LÄRANDE.
LÄRARE OCH ELEVER UTVECKLAR OCH FÖRDJUPAR DET EGNA LÄRANDET OCH DEN EGNA FÖRSTÅELSEN.

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SAMMANDRAG

En ny läroplan för de finländska skolorna togs i användning år 2006. Kemi och fysik skulle enligt den undervisas som skilda ämnen redan i klass fem och sex på lågstadiet. Några hög- och lågstadielärare bildade för några år sedan spontant en grupp, PLOT-teamet (Problembaserat Lärande Och Tutorskap), med uppgift att hitta på passande experiment för dehär klasserna. Målet var att göra experimenten tillräckligt lätta för att de skulle kunna utföras i vanliga klassrum med liten utrustning. En annan viktig omständighet att beakta var klasslärarnas oftast små kunskaper i fysik och kemi. Djupgående kunskaper i dessa ämnen kunde alltså inte förutsättas. Beaktande dessa utgångsvillkor beslöt gruppen att ansatsen skulle vara problembaserad.

Förehavandet att samla data och skriva en text, som förklarar data, är narrativt. Narrativitet bör dock inte betraktas som en forskningsmetod, utan utgörs av många osammanhängande frågeställningar som hänför sig till berättandet. Ansatserna är alltså många och olikartade. Kärnan i narrativ forskning utgörs av analys av berättelser. Sådan analys ger upphov till en ny berättelse utgående från berättelserna i data. Denna berättelse, som har tolkats från the ursprungliga texterna, är i sig själv fiktiv. I min studie producerar jag en narrativ genom att tolka de berättelser, som utgör mina data. Min studie sonderar alltså erfarenheterna hos PLOT

medlemmar, lågstadielärare, och studerande under övergångsperioden till den nya läroplanen. Jag betraktar min värld med hjälp av system. Enskilda personer och organisationer ser jag som delar av större system. I stället för att betrakta organisationer som mekaniska strukturer bestående av uppgifter eller människor skall de ses som levande organismer som utvecklas och anpassar sig till en föränderlig omvärld.

De producerade laborationsuppgifterna för fysik- och kemiundervisningen i klasserna fem och sex kan betraktas som en innovation. Innehållet är nytt, det utgör en förbättring, sättet att arbeta är bemyndigande för studerande, en förändring äger rum. Den grundläggande anpassningsprocessen är en inlärningsprocess. Konceptet ”lärande” framträder som konstruktivt och kan förstås som en biprodukt till socialt engagemang. Lärandet är en iterativ process, som äger rum i en dialektisk rörelse mellan handlande och eftertanke, då de lärande rör sig ut i omvärlden och in i sig själva. Resultatet av en cykel utgör råmaterial för följande cykel. Varje cykel innehåller självreglering, kollaborativt handlande och kommunikation.

Den ursprungliga avsikten med detta arbete var ett försök att möta de fordringar den nya läroplanen satte. Emellertid skiftade inriktningen mot en studie av lärandet i sig och skolan som en lärande organisation. I början koncentrerade jag mig på studerandes lärande i grupp, studerandes motivation och förståelse av det egna lärandet. Men också de lärare som försökte införa problembaserat lärande som undervisningsmetod märkte att de började tänka på ett nytt sätt. De lärde sig hur de skulle undervisa. Denna process, lärande som en följd av att samarbeta i ett team, blev den viktigaste delen av min studie. Lärarnas erfarenheter av de workshoppar som de organiserade för lågstadielärarna var speciellt värdefulla när vi tänker på pågående och framtida utveckling. De olika kulturer som härskar i lågstadier och högstadier framträdde klart. Då nu sammanhållen grundskola införs, måste detta beaktas.

Denhär studien har haft stark inverkan på lärarna i PLOT teamet. Den har bidragit till utvecklandet av deras potentiella anlag som lärare, undervisare och handledare. Den har också avslöjat svårigheter att införa öppna frågor i läroplanen för naturvetenskaper, speciellt i lågstadierna. Den kultur att undervisa faktakunskap som härskar i lågstadierna

motsätter sig öppna frågeställningar enligt vilka alla utgångspunkter är meningsfulla för den lärande och därför bör användas av läraren. PLOT metoden, som använder sig av främmande experter, har också öppnat dörren för djupare samarbete med industri och företagare.

Team har en central roll i den kunskapskreativa processen. De tillhandahåller en gemensam interaktionsomgivning i vilken nya perspektiv kan skapas i dialog. Därigenom kan gömd kunskap göras öppen, uttalas, öppen kunskap kan sammankopplas, internalisering äger rum. Kommunikationen mellan team medlemmar och mellan team har tagits i beaktande som en möjlighet att utveckla inlärningsprocessen i organisationer. Kunskap är inte enbart information, fakta. Kunskap är också en dynamisk mänsklig process där personlig övertygelse berättigas. Kunskap, skicklighet och prestation är inte statiska storheter utan de utvecklas genom ökade och ändrade erfarenheter. Individer i ett team måste klara av att anpassa sig till ändrade fordringar. Fortgående lärande är en viktig synpunkt på team utveckling. Lärande är ett sätt att finna mening genom nya idéer och erfarenheter. En spiralliknande rörelse uppkommer då lärandet baseras på en diskursiv process och det aktuella materialet ifrågasätts från olika perspektiv. Jag hoppas att de stora individuella potentiella resurserna skulle tillåtas att utvecklas i kretiva, innovativa team i våra skolor. Detta skulle förbereda våra studerande för kunskapssamhällets krav på samma gång som deras lärare skulle utvecklas till lärande och kunnande handledare, som skulle uppleva varje ny dag i skolan som ett underverk.

Acknowledgements

When in 1962 I started my university studies with the intention of becoming a schoolteacher of mathematics, physics and chemistry, I did not realize where this path was going to bring me. Already in the sixties it became clear to me that I wanted something else from life than what the profession as a teacher could offer. Thus, being offered the possibility, I started a research carrier in nuclear physics. Thanks to my professor K.V. Laurikainen I got an education not only in nuclear physics but also in life knowledge. He taught me to question and search for answers. He offered himself as an ideal searcher in that he after having finished his carrier as a nuclear physicist began a study as a researcher of philosophy.

My life path led me back to the profession of being a teacher at the beginning of the nineties. I was a rebellious teacher in that I wanted to understand the reasons for the pedagogy I was supposed to use. Thus I started my studies in education. I made my master's thesis under the supervision of Dr. Tuula Keinonen, who since then has been my support and discussion partner. She has guided my work on the draft of my doctoral dissertation. For her patience, encouragement and time consuming reading and commenting of my texts I can never express or show my deeply felt gratitude. Except for her devotion to her task as tutor there would have been no dissertation.

I want to thank my supervisor Professor Marja-Liisa Julkunen for her support. She has been able to give her time for discussions and has encouraged me to go on with the work. At times when my teacher profession threatened to intervene too much with my studies she adjusted her own schedule, for example to agree with my possibilities to take part in seminars. My gratitude is deeply felt.

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It is a pleasure for me to express my gratitude to friends and colleagues at Mattlidens skola. The principal FM Ingrid Lindquist-Stenman had to

endure an oppositional teacher that instead of fulfilling her teacher duties mostly was on leave for studies. I am grateful for her understanding. I also want to thank the director of the educational board for the Swedish schools in Espoo Barbro Högström and her head of instruction Maj-Len Engelholm for shown appreciation and support. FM Jan-Anders Ray offered many hours of his free time to correct the language of my manuscript. Last but not least the members of the PLOT team must be remembered. They feel that this work I call mine is also theirs. I am happy that this is so.

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My family has had to stand back during the years of my study. I more or less abandoned my two sons at the most critical years of their development. Today I can only feel grateful that they have developed into young grown ups that any mother can be proud of. They have given me support in my studies these last years, when we all three have devoted ourselves to our graduate theses.

Espoo, 24 April 2007,

Sivbritt Dumbrajs

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1. Introduction

Heaven does nothing; this nothing-doing is dignity;
Earth does nothing; this nothing-doing is rest;
From the union of these two nothing-doings arise all action
And all things are brought forth.

Chuang Tse

The modern human being is overwhelmed with information. There is no possibility for a single individual to master all knowledge offered by society. Schools and other educational institutions have to consider what to teach and how to teach in order to develop the right sort of individual skills to cope with this situation.

Life is full of possibilities. As human beings we can make choices that influence our lives. There are also things that cannot be influenced, only accepted as belonging to life. When choosing among the intellectual possibilities of life a critical, but positive, relationship to our surroundings is helpful. We may ask ourselves questions. What good can be achieved from this experience? Which important things can we learn from this situation? We have to decide what sort of knowledge we need and how to use our intelligence in a purposeful, logical way in order to develop our wisdom. Also we should carry responsibility for our choices ourselves. To which degree do we value intellectual use of factual knowledge? Does affective knowledge have some influence on our lives? It is all too easy to put the responsibility for failure on someone else's shoulders. Of course, the starting point in life is different for all of us, someone "is born with a silver spoon in the hand", someone else "on the shady side of the street", but the manner of building relationships to the society in which we live is our own choice.

The affective aspects of knowledge play an important role in our lives. Our affections give us strength to perform also in very difficult situations. They disclose our deepest motives. They give meaning to the factual world in which we live. Tacit knowledge guides us when we make our choices. Intuitively we reject some possibilities and choose some other. We feel what is a good choice and what is not. If we do not allow our feelings to reveal themselves, there is a danger that our lives will be extrinsically

directed. We will listen to directives from the society. A self-directed way of living is impossible, because our self is disclosed primarily in our feelings and our way of meaning making. Through learning to know our self we also find the route to interaction and communication with our fellow beings.

In the following subchapters and in the second and third chapters aspects on some concepts of interest for my study will be presented as footnotes in the case that they deviate from or are of minor interest seen from the perspective presented in this study.

1.1 What is knowledge?

To live is to know (Gonçalves 1997, xii; Heidegger 1927, 144).[1] Human beings are intentional, dynamic and self-organizing. They are creative in their existence and knowing in their creativeness. Knowledge is hermeneutic in the sense that it allows multiple interpretations. Hermeneutics can be seen as a narrative discourse, where meaning is constructed in language. We think in the same way as we live, through narratives (Peavy 1997, 127). Thus narrative can be considered as a mode of knowing (Czarniawska 2004, 6). A similar mode is the experience of a work of art, which according to Gadamer (1975, 84) allows us to partake in knowledge.

According to Gadamer (1975, 347) past experiences provide future experiences with horizons of expectation. We assume new experiences to cluster according to our expectations. In an everyday sense experience reinforces fore-conceptions. Yet experience can also be thought of as a meeting with what is new and different. Then experience is firsthand an

1 The concept of knowledge used to be studied by philosophers. With the beginning of the knowledge age at the very end of the last century this situation changed. Nonaka and Takeuchi (1995) discussed the dialogue between tacit and external knowledge that drives creative processes. Bereiter (2002) substituted folk theory by a theory of conceptual artifacts that are linked in logical ways; they form a system or a state of knowledge (Bereiter 2002, 468). According to Bruner (1990, 39) when constituent believes in a folk psychology are violated narratives are constructed. Narratives describe our lives.

experience in negative respect (Gadamer 1975, 350). Something is not as it was assumed. The object of the experience is seen in a different light; it has changed. And we ourselves have also changed, when we know that the object is different. The new object contains a new, deeper truth. The dialectic completeness of the experience is not found in cognizance but in the disclosure against the experience. (Palmer 1969, 196)

Experience clearly does not mean informative knowledge; experience implies the accumulation of understanding that is called wisdom (Gadamer 1975, 350). For example an individual that all her[2] life has been involved with diverse persons develops a skill to understand these. This skill is called experience. It is knowledge about how things are; it is insight into human nature. Such experience is not a knowledge that can be objectified neither is it a pure personal skill. Experience ruins our illusions in miscellaneous ways. Negation and vitiation of illusions are indispensable for experience, because experience arises when a hope is destroyed. Experience often includes the pain of growing and new understanding. We would like to save our children from bad experiences, but it is impossible because experience belongs to the historicity of human beings (Gadamer 1975, 350). Through suffering the human being learns to know the limits of being. She learns to understand her limitation. She learns that she cannot control time. An experienced individual knows the limits of her expectations, the insecurity of all manmade plans. In experience the skills of man to do and to decide reach their limits (Gadamer 1975, 351). In history man acquires knowledge about the future, in which expectations and plans still are open in front of him, through experience. A mature experience that places man in the disclosure of future and past is in itself essentially what Gadamer means with a historically operating awareness.

2 I apply the convention to use feminine gender for humans throughout this study.

1.2 School as a learning organization

Schools will have to change in order to meet the demands of the knowledge society.[3] It is an important goal of education to achieve empowerment of the students. Students supply a rich pool of talent, enthusiasm and determination. They should take ownership of their education and drive it to the highest possible standards in a working partnership. (Mortimer and Scott 2003, 21) According to the model of self-directedness the student forms and carries out her own personal intentions. Teachers will act as facilitators and scaffold builders investing their students with increased power and responsibility. In this way students could be prepared for the knowledge society. (Mortimer and Scott 2003, 128)

To change the school world in the direction suggested above it is necessary to redesign the whole process of teaching and learning. According to Senge, Cambron-McCabe, Lucas, Smith, Dutton, and Kleiner (2000) school must be a learning organization in a wider sense than at present. Teachers should learn how to improve the processes of teaching. This may take place in collegial groups or teams, in which teachers learn to reach out to each other for help to improve their school and their classroom. They also should use outside resources as much as possible to meet their goals. Thus teachers would not be only facilitators and guides for their students, but they would themselves be life long learners. They must identify needs, the solutions to these needs, and the results they get. They own the process.[4] (See e.g. Marton and Tsui 2004, 3-21; Cranton and Carusetta 2004, 5)[5]

3 Bereiter (2002,215) wants to bring back liberal, humanistic education values like freedom and development of the inner capacities of the student. The education should not comply with the ongoing demands of the society, but be seen in a wider perspective of time. As he says "students should join the ranks of those, who are familiar with, understand, create and work with the conceptual artifacts of their culture". Marton and Booth (1997, 175), contrary to this, see learning as a gaining of knowledge about the world or coming to experience some aspects of the world in a particular way. In organizations the need of empowerment of learning teams and employees is emphasized (Hoover 2002, 111).

4 On the other hand Bereiter (2002, 221) strongly opposes this design. He sees that ability to acquire new knowledge depends almost solely on prior knowledge.

5 The order of references given in brackets is: first the ones most relevant to my study, then supporting references and finally those that take up another perspective. References in other languages than English come last.

On the level of organizations some new features are added to the individual learning process. The individual ways of thinking are integrated in order to achieve a common purpose and common norms of action. So created visions, values and performance strategies spread and survive in the organization unconnectedly to dismissal or new employment of individuals. Each organization learns as each individual employee learns, but if integration does not take place the learning outcome can be negative and end with chaos. (Hoover 2002, 90-96; Senge 1990, 14; see also Nonaka and Takeuchi 1995, 59-71)[6]

1.2.1 The learning organization

For a learning organization, adaptive learning must be joined by generative learning, learning that enhances our capacity to create (Senge 1990,14).

The development of an organization's learning can be seen as an evolutionary process. When an organization must pay all its attention to production and resources in order to survive, it will learn only through trial and mistakes. Also, if employees for example are professional short-term craftsmen, it might be assumed that they themselves attend to the maintenance and development of skills and know-how (Strömmer 1999, 188). The employee also learns in her work situation. Core skills that each employee should have are defined. The work group or team takes care about developing these skills in the members. Then leaders are responsible for the learning processes of their subordinates. Some organizations function for long times without any conscious need or wish to learn. (Koslowski, Gully, Nason, and Smith 1999, 243; Ruohotie and Honka 1999, 164)

But when the organization grows, a crisis springs up or when competition becomes strained, a need for schooling arises. Employees are sent to partake in suitable courses (Strömmer 1999, 188). Schooling is a commodity that is acquired just like other products and services. Still the

6 Bereiter (2002, 182) opposes the idea of Nonaka and Takeuchi that knowledge can be created only by individuals. If one understands knowledge as consisting of conceptual artifacts, knowledge can be a social product.

individual learning is independent of organizational functioning. It is just expected that the individual is able to apply and use her new knowledge at her workplace. At a later stage it is realized that a more economical solution is to bring the training programs inside the organization. An instructor is invited to teach generally needed skills like communication and technical abilities to a large group of employees. Someone in the organization might get taking care of the schooling program as her responsibility. But still there is no clear connection between an expected improvement in performance and the learned skills. When a curriculum that takes into account strategic goals is developed and applied, learning is focused on the needs of progress inside the organization. Coherence of suggested learning scopes, continuity and reciprocal relations are considered. A department inside the organization is often responsible for the program of development. (London and Mone 1999, 119; Strömmer 1999, 188-190)

In a learning organization functioning is decentralized, work processes are holistic and meaningful. People are listened to. They commit themselves to continuous cooperative learning and development of work processes. Commitment, loyalty and putting the advantage of the whole before one's own profit are features that in the vision of a learning organization are seen as individual characteristics. However, the present era of downsizing, retrenchment, high unemployment, diminishing training budgets, flexible working and short time contracts has revealed the dispensability of people (Kamoche 2001, 18). When the organization finds it suitable or necessary, personnel is reduced "for the advantage of all of us". Human resources are seen just as standing reserves without dignity, a target for reduction to slavery (see Heidegger 1977, 53-112).

An organization should not always look for expertise from outside. If the culture of the organization is not supportive, suitable technology does not exist, or communication is insufficient, then to persuade high performers from other organizations to change employer may not serve the intended purpose. Also the potentially available expertise inside the organization is to be considered. What strategies can be developed with the available resources? But fears exist that employees receiving training will not stay with the enterprise long enough for it to retrieve its

investment. (Kamoche 2001, 39) Do employees consider that they are committed to the organization and that their contribution has a value? Employees that perceive a lack of reciprocity in commitment in the form of job security might feel free to put their own advantages first.

But a few organizations that give highest priority to development in the direction of a learning organization as defined by Senge exist (according to Smith 2001): "..organizations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning to see the whole together." Most companies' priorities are financial. It is too idealistic to show a fundamental concern with the learning and development of employees. But there are organizations that do not look for profits, too. In many comprehensive schools teachers are paid according to the amount of lectures delivered in class. Nowadays the lecturing, however, is only a part of the work they are obliged to do. In a way, therefore, teachers are used to improve their own learning about teaching just because they want to. They do not expect to be paid for their efforts. Could such a school develop features of a learning organization more easily?

1.2.2 The vision

While all people have the capacity to learn, the situations in which they live and work do not always allow for reflection and engagement. People may also lack the tools and ideas to make sense of their surroundings. However, if someone has been the member of a top performance team, she will find the experience meaningful. She will mention the feeling of being part of something larger than herself, of belonging somewhere, of being generative. This was a period of her life lived to the fullest. (Senge 1990, 13)

Generative learning includes mastery of certain basic disciplines. Humankind has developed scientific knowledge by adopting an analytical method to understand problems. The method is deductive; it involves breaking the problem into components and then studying each part separately. Thereupon conclusions about the whole can be made.

This method is not applicable to modern complex problems. Linear and mechanistic thinking must give way to nonlinear and organic thinking. (Marton 1996, 174; Bystedt 2001) Then people are induced to reflect on the whole system; systems thinking appears (Senge 1990, 90-92). Systems thinking works by expanding its view to take into account larger and larger numbers of interactions as a problem is being studied. This sometimes results in very different conclusions than those generated by traditional analysis, especially when what is being studied is dynamically complex or has a great deal of feedback from other internal or external sources. The viewpoint of the systems is usually long term. Short-term improvements often might lead to long-term impairment; just consider using pesticides against insects in the kitchen garden and the accompanying risks of poisonous vegetables.

Alongside systems thinking there stands the discipline of personal mastery. It goes beyond competence and skills. It includes a continual clarifying and deepening of the personal vision. People with a high level of personal mastery see life as a learning enterprise (Ruohotie and Honka 1999, 128). Personal mastery is a process, a journey through the different cycles of life that is a reward in itself. (Senge 1990, 142) Individuals who practice personal mastery experience changes in their thinking. They learn to use both reason and intuition to create. They become systems thinkers who see the interconnectedness of everything around them and, as a result, they feel more connected to the whole. It is, according to Senge, this type of individual that one needs at every level of an organization for the organization to learn. (Senge 1990, 139; Simon 2004, 34)

The way one looks at the world forms a mental model (Simon 2004, 78). Mental models for dealing with emotional or threatening issues are developed early in life. According to them we act and interpret the actions of others. As soon as we understand the flaws of our mental models we can start to examine and change them. This learning experience preferably takes place in open conversation with others who also expose their models for inspection. (Senge 1990, 9)

In systems thinking the vision can be a leading star for the individual. Only by development of the individual visions in a common direction

the shared vision arises. Many leaders have visions that never become shared visions. The organizational vision must not be created by the leader, but through interaction between individuals in the organization. A shared vision fosters genuine commitment rather than compliance. If a learning organization has a genuine vision, people learn not because they have to but because they want to. (Wilemon and Thamhain 1983; West 1990, 309)

London and Mone (1999, 127) accentuate the importance of synergistic learning, i.e. construction of shared meanings and assumptions. Team learning builds on personal mastery and a shared vision and should lead to performance. The team supplies a shared context for interaction in which new points of view are created through dialogue (Hoover 2002, 20-25; Nonaka and Takeuchi 1995, 13). Knowledge is not just information, or facts. It is also a dynamic human process for justifying personal belief (Nonaka and Takeuchi 1995, 58). One of the key elements of team learning is a willingness to deeply explore a problem. We can develop this skill individually using personal mastery, but something unique happens when we bring our willingness to explore a problem into a group situation. The group can coalesce and the members begin to use each other as a springboard for understanding and resolving the problem at hand. When this happens, the solution the group has developed is above and beyond the work that any team member could have done individually. (Kozlowski et al. 1999, 243)

1.3 Motivation

Murphy and Jackson (1999, 325) define an organization's motivational system as including "all elements of the system intended to shape the direction, intensity, and persistence of performance-relevant behaviors". Trends of change reflect a shift from bureaucratic work structures to forms that relay on work roles. Teams may provide the possibility to change both task and role (Murphy and Jackson 1999, 346).

A self-determinative motivation develops in surroundings where psychological needs might be fulfilled and where it is possible to reach

autonomy. If important contact persons and supporters are available an experience of individual competency arises (Deci and Ryan 1993). In school surroundings the mission of improvement of education rests on the shoulders of the boards of education. Administrators have to learn what empowerment is and what it can do for their schools. They must enable staff to take a collaborative approach in solving the challenges in front of them. Empowerment is important because it is powered by energy. It is about willingness to try new ideas, a wish to improve things and a preference for working together in teams. Empowerment deals with motivation. Motivation is a mental condition, connected to some certain situation that defines how intensively, with how much activity and diligence an individual acts, and in which direction her interests are headed. The integration of certain behavioral features is an important task of the society. (Hoover 2002, 111)

There are three main energy sources that feed motivation, i.e. physiological drives, emotions, and psychological needs (Deci and Ryan 1993). Some conditions of the environment facilitate, others inhibit the satisfaction of needs. Thereby the appearance of intrinsic respectively the integration of extrinsic motivation is influenced. Intrinsic motivation is connected to feelings and experiences that influence the wish to act in a certain way. Extrinsic motivation has its roots in the environment. Society expects us to act according to special patterns. Extrinsic motivation is connected to rewards and fame (Argyris 1992, 236). If the extrinsically motivated act is not awarded in some way, the motivation expires. (Deci, Koestner and Ryan 1999, 627)

Values and aims in life have a big influence on motives. Each individual has needs, wishes and expectances (Hoover 2002, 9). These are changing with time. They can also contradict each other. When a motive is reached, this influences behavior and future motives. The importance of personal motives is individual. Motivation is hypothetical, grounded on assumptions. It is a conceptual scheme that helps us to understand behavior. There are many reasons why it is difficult to decide about motives from the experienced behavior. Behind a single act there can be many motives. The motives can appear in a hidden form. Similar motives can be expressed with different behaviors. Cultural and personal

variations can influence the appearance of some motives. Motivation is not defined only by the individual's intrinsic unbalance and extrinsic stimulation, but also by her experienced situations, obtained information, and interpretation. (Ruohotie and Honka 1999, 13)

1.3.1 Motivation and self

Self-conception, self-esteem and competence are concepts closely connected to motivation research. Our self-conception is formed through the roles that we take up in our lives (Simon 2004, 26, 27). It is our individual judgment of our selves. Self-esteem is something positive. In a very general way it defines our good sides. Experienced competence together with self-conception and self-esteem forms the foundation of our personality and general well being. (Argyris 1992, 297; Aunola 2002, 116; Ruohotie and Honka 1999, 25)

Autonomic behavior is an intrinsic feature of human beings. Autonomy is according to the theory of self-determinative motivation one of the basic human psychological needs (Hoover 2002, 10). This need we try to satisfy in our social environment. The amount of self-determination (Simon 2004, 51) in activities can be described as a continuum between amotivation and intrinsic motivation. By intrinsic motivation the individual takes part in action with eagerness and enjoyment. Amotivation means lack of motivation. (Jaakkola and Liukkonen 2002a, 109) The atmosphere in the premises affects the degree of motivation that the workers experience. It can satisfy the competitive, self-directive and interactive needs. Then extrinsic motivation might change to internalized motivation. This means that we take part in action of our own free will, experience the activity as interesting, and feel committed to the goal. (Murphy and Jackson 1999, 338; Aunola 2002, 118-124)

A human being acting in an autonomic way can be considered to act authentically. Autonomic extrinsic behavior may be integrated and internalized to a part of the self. It will be experienced as self-control of one's activities. Then the individual discloses her own self in a true way. Autonomic action thus is very different from controlled action. (Argyris 1992, 215)

The motivation for action is to a large degree dependent on the aim (Ruohotie and Honka 1999, 16). The more important it is to reach the aim, the more motivated we feel. Limited, but demanding challenges to which we feel committed give us a feeling of pleasure and enjoyment. The aim can be connected to performance, like learning to skate, or to reach some goal, like saving a certain amount of money. (Jaakkola and Liukkonen 2002b, 171) Increase in performance demands a motivation that is optimal. A combination of both aims forms a process, where we need to improve our performance in order to achieve a goal. Then also the expected pleasure motivates us. (Malmberg and Little 2002, 130)

Often there is some sort of reward for good performance. This reward influences the motivation. We all feel pleased, if our surroundings attach attention to our performance. Praise and celebration of our achievements can increase our motivation. A reward in money is always welcome. (Hoover 2002, 15) But, if we get used to extrinsic rewards, our intrinsic motivation might diminish. The day there is no reward we do not feel motivated to go on with our activity. (Aunola 2002, 118; Jaakkola and Liukkonen 2002c, 147; Jaakkola and Liukkonen 2002d, 26; Ruohotie and Honka 1999, 46)

1.3.2 Motivation and teams

A team is comprised of two or more individuals who waive their own skills and knowledge for the use of the team. They interact dynamically in order to accomplish a common task. A collaborative atmosphere can be achieved through open-minded discussions and conversations. When a team is at its best, the work includes continued learning and experimentation. (Murphy and Jackson 1999, 340; Hoover 2002, 14: Ruohotie and Honka 1999, 100-102)

According to Strömmer (1999, 157) it is important for performance motivation that individual efforts can influence the success, the tasks are suitably difficult, success can be measured or feedback is given, there is place for creativity, and there are future performance goals.

Extrinsic rewards can be earned as a result of belonging to a team. Then they are not connected to the task, but to the appointment conditions, as pensions, vacations and insurances in case of disease. The leader of the team can give an award for a good job. The other team members can also acknowledge an individual due to her social and/or personal qualities. Extrinsic rewards can influence the social climate and feeling of togetherness in the team. A team can be motivated by extrinsic rules that are due to justifiable authoritative sources. The motivation then has little connection to the task to be performed. Rules might become norms for action. The team members loose their self-directedness and it becomes improbable that they would take initiatives of their own. Through deindividualization, a situation where the personal responsibility and identity is diminished, the team motivation can be influenced in a negative way. Very strong feelings of belonging together might cause a person to give up her earlier principles and her command of herself. Then she does not take responsibility of her activities but shifts it upon the team. Her performance and thus also the performance of the team is diminished. (Murphy and Jackson 1999, 351; Ruohotie and Honka 1999, 115)

Intrinsic motivation of a team can be achieved when individual members experience pleasure and are motivated because of their performance in their roles. For example a cook is content when she can use her skills in as good a way as possible for the good of the team. When the goals of the team are internalized as a part of the individual motivation, the member experiences a change of her system of values and of her self-conception. The reward is not money or other advantages, but a change or development of the own identity. (Murphy and Jackson 1999, 338; Ruohotie and Honka 1999, 116)

Happiness is not something we just get or do not get. But we have all experienced how we momentarily control our acts and form our destiny ourselves. We then feel exhilarated and deeply pleased. Remembering these moments we realize that this was an instance of happiness. (Jaakkola and Liukkonen 2002d, 27)

In a high performing team something that cannot happen in normal groups takes place. When the project evolves the team members reach higher and higher levels of personal performance and enjoy their work to a much higher degree than they would as individual workers. A high performance team is much more than the sum of first class individuals. To have success in one's own work, to learn new things, to try hard, and to see errors as an essential part of learning, these features delineate thrifty individuals and prosperous teams. Experienced autonomy and competence, social interrelationships and experienced importance, challenging projects, efforts, enjoyment and pleasure are attributes of a team with "flow". Such a team is a high performing one. (Csíkszentmihályi 1996, 17-22).

1.4 Aims of the research

According to Marton and Booth (1997, 139) learning takes place and knowledge is born when some change is experienced. This can be caused by an interaction between teachers and students and/or by face-to-face communication between peers or experts and novices. Motivation is the matchstick for the change (Strömmer 1999, 150).

My research concerns school as a learning organization. Constructivism and narration, together with the socio-cultural theory of learning, form the background of the research. Constructivism helps us to understand how our life-world is built and the narratives we tell each other describe our lives.

Earlier recognized features of performance in organizational learning suggest that problem based learning (PBL) in communicative teams gives the learner an autonomous role in which she directs her own work. She develops creative features. She finds new, innovative solutions to problems. The intention of this research is to find changes and development in teachers and students both concerning their way of teaching and learning and their personal opinions about their own learning process. My research problems are:

1 Subject teachers' experience of their own metalearning by learning how to teach class teachers and students in accordance with PBL material developed during the process.
2 Students' experience of problem based learning in collaborative groups.
3 Class teachers' experience of learning to teach as facilitators in a PBL context.

A new curriculum planned for the Finnish schools was taken into use in 2006. Chemistry and physics were then taught as separate subjects already at grades 5 and 6 in primary school. A spontaneously formed group of secondary and primary school teachers, the PLOT team, PLOT standing for Problem based Learning and Tutorship (in Swedish Problembaserat Lärande Och Tutorskap) decided some years ago to find suitable experiments for these grades. The aim was to make the experiments easy enough to be performed in ordinary classrooms without much equipment. Another important feature to consider was that the class teachers generally do not know very much physics or chemistry, which means that the experiments should not demand deep knowledge of these subjects. Considering these conditions it was decided to make the approach problem based (Barrows 1985, 108). The group of teachers involved met every third week. During the meetings discussions of new ideas for experiments took place. The experiments were then tested in primary schools. Thereon the teachers rewrote the instructions according to the test results and wrote teachers' guides.

I use qualitative methods to investigate the learning process in the PLOT team and in groups of students and primary school teachers. In this study I applied action research both independently, when the PLOT members were the test subjects, and together with the PLOT members, working alongside me, when students and class teachers were test subjects (see e.g. Kemmis and McTaggart 1988, 18). This included interventions in the real school world and examination of the effects of these interventions. Each cycle contained self-regulation, collaborative action and communication. The data collection methods were deep-going interviews and partaking observations.

The final reference frame of theory developed during the research period, all the different pieces falling into place only as the work was finished. The theory presented in the next chapters is a result of this process and thus represents my personal view of the theoretical background to the process of learning. Another researcher would probably have developed somewhat different solutions. Further on, during the period of study I gathered many insights and the influences have slowly built up during years of reading relevant literature. Thus I focus here on presenting and describing my own understanding in my own frame of reference.

I have tried to summarize the research process in Figure 1. The research problem is stated above and concerns subjects' reactions to change, which implies learning and metalearning. I use a theoretical perspective on this change process supplied by organization psychology and grounded in systems theory and constructivism. The research method is action research, where the analysis is performed by applying phenomenography and hermeneutical interpretation. The subjects of my research are the members of the PLOT team consisting of four subject teachers (including myself) and one class teacher (N=5), class teachers (N=14) and students. My theory defines the plot of my narrative, the intrigue of team formation and development in a learning community (Czarniawska 2004, 101, 125). The method of investigation supplies me with an interpretation of the occurrences (Syrjälä and Heikkinen 2002, 158). The subjects are the actors or characters of the narrative (Bruner 1990, 43).

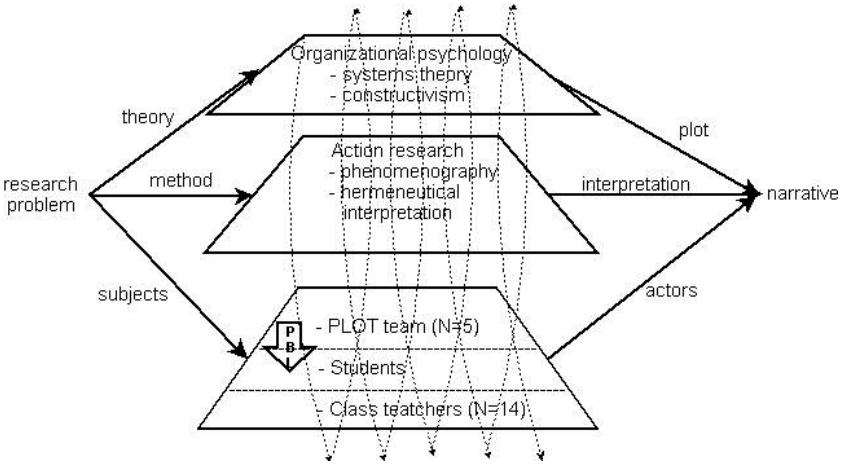


Figure 1. Scheme over the research process. The dotted curve shows the hermeneutical spiral as applied during the research process.

In chapter 2 I describe my world from the point of view of systems. A system is defined as any set of interdependent or temporally interacting parts. These parts may be systems themselves, which are composed of other parts. Individuals and organizations are seen as participants in a larger system. Rather than understanding organizations as mechanistic structures of tasks or people they are truly living organisms that evolve and adapt to the changing environment. The primary process of adaptation is the learning process. An active modification of individual thoughts and ideas as the result of experiences features a constructivist learning process. The process is iterative. The products of one cycle become the raw material for the next cycle.

In chapter 3 school as a learning organization and teachers and students as learners are viewed from the perspective of organizational psychology. The psychology of team formation, team learning and team performance is applied to the school world. The importance of good communication and treatment of conflicts inside the school community and especially inside teams is stressed. Different definitions of the team concept are discussed.

In chapter 4 the range of my research is limited to more concrete research questions inside the wider range of the research problem. Then I present the methodology that I use in the action research process. When I have interviewed the PLOT team about a theme and thus have several interviews concerning the same question, I use phenomenography to find the categories of meaning. I thereby loose information concerning the informants, but gain confidence in their meaning making. Here as well as in analyzing single interviews, observations and study materials I have interpreted the data hermeneutically using the hermeneutical circle. This means that I read the texts repeatedly trying to find a holistic picture of the events. I want to find out what the text says, why it says what it does, how it is doing it and what I as a reader think about it.

The fifth chapter contains my narrative. This has a plot formed by theory of teams and organizations and founded in systems thinking. It also includes analysis, results and a preliminary discussion. The theoretical background or plot, the analysis, the results, and the reflection on the results together form the narrative in accordance with narrativity principles (Czarniawska 2004, 124). My intention is to describe the nature of a change process, i.e. I take an ontological approach to my research problem. But intrinsically to the change process epistemological questions arise. How do subjects learn in a change process? What models for knowledge development should be supplied by school?

In the sixth chapter I give a short summary of my research results as they protrude in the narrative. I also compare the work of the PLOT team to other similar ventures. The validity of such research as I have done is discussed. The benefits of using teams in the school world, both for teachers and students, and especially the positive influence on the learning community as a whole, is acknowledged. Importance of dialogue and interaction in the class room, also and especially in the form of narratives, as lately discussed in educational literature, is considered as a future step of investigation.

In the next chapter I will elucidate the systemic background of my study. Of special interest to me is the connection found between systems theory and constructivism. Maturana (1988) claims: “The big bang, or whatever

we claim from our present praxis of living gave origin to physical versum, is a cognitive entity, an explanation of the praxis of living of the observer bound to the ontology of observing. Our happening of living takes place regardless of our explanations, but its course becomes contingent upon our explanations as they become part of the domain of existence in which we conserve organization and adaptation through our structural drifts. Our living takes place in structural coupling with the world that we bring forth, and the world that we bring forth is our doing as observers in language as we operate in structural coupling in it in the praxis of living."

2 Systems

During the Age of Enlightenment distinct reasoning was a crucial aspect of thinking. Research was seen as being free of presuppositions. Humans were supposed to have a natural evaluative capability and thus an ability to distinguish a true thought from a false. Rationality, being the designating property of human beings, was assumed to be present in perfection in each individual.

Descartes was probably the first one to use the word "reflection" in the meaning to be aware of ones thoughts (Markova 1982, 18). All three words – awareness, thought and reflection – depend on each other in regard to meaning. This indivisibility unites the present and past self. Thought and awareness were given to man as a birth gift. As such they are features of the human mind. This conception leads to the dualism of the world: there is both a world of awareness and an objective world. The mind is a thinking substance without extension, while the body is not thinking but has extension.[7] Thus the Cartesian dualism is born. One does not have direct information about the objects in the world but, on the contrary, about the contents and activity of mind. Knowledge about outer beings arises through the mind, not through the senses. Hermeneutics as a theory of interpretation is directly influenced by such an impression. Interpretation gives the means to control objects. Thought is not creative but becomes manipulative and contriving.

A new way of thinking became popular when computer systems were developed. Humans were regarded as parts of a system that is self-maintaining and self-evolving (Ashby 1956, 196: Rocha 1996). The input- and output-functions of computers were compared to how the human brain reacts to sensations. Concepts of feedback and information were generalized to include systems of living organisms, abstract processes and language. A constructivist view of the world (Glasersfeld in Matthews 1994, 149, 154) according to which objectivity derives from shared agreement about meaning and information is an attribute to an

7 In sharp contrast Nonaka and Takeuchi (1995, 10) understand that mind and body form an oneness.

interaction was adopted. Learning is seen as a process of continuous change.

The word "system" has two roots in ancient Greek, meaning "together" and "to cause to stand". "Systematic" refers to things combined into one whole. Systems thinking means that thinking takes place in terms of connections within some complex entirety. In self-organizing or autopoetic systems positive feedback loops (Argyris 1992, 68, see also 157) are understood as a source of new order and complexity as the system develops new patterns and organizes itself. A particular phenomenon is always a part of a pattern. In general systems theory the same patterns of organization are assumed to form the ground in different disciplines. In second order cybernetics it is assumed that any observed system includes the observer. (Foerster 1995)

2.1 A different worldview

During the Age of Enlightenment science was regarded to be causal and time reversible. Newton's three laws of mechanics nicely described small as well as big physical systems. It seemed that science had reached its end; only ordering and systematization remained to be done. But classical science had ignored many problems, such as irreversible evolution processes and natural processes in the atmosphere and in the sea. At the latest with the beginning of the Age of Modern Physics it became clear that there are irreversible, unpredictable processes. Heisenberg's uncertainty principle stated that in all phenomena, and significantly in the micro-world of quantum physics, it is in a quantum mechanical system impossible to make a precise, simultaneous determination of both location and momentum of a particle. Increased precision in measurement of one quantity results in increased uncertainty of the other quantity. Also the well-known wave – particle duality is a manifestation of the uncertainty principle. For example, electrons behave as waves in diffractive processes but as particles in the photoelectric effect.

Change processes in the system of the natural sciences must be seen as development of a series of episodes of normal science alternating

with periods of scientific revolution (Kuhn 1962). Each episode is characterized by a paradigm. Too many anomalies inside one paradigm constitute a crisis. In a revolution a new paradigm will replace the old one with which it is incommensurable. The choice between theories from different paradigms involves not only experiential facts and logic but also persuasion and judgment (Kuhn 1962, 23, 43, 152).

Ackoff and Emery (1972, 218) developed the thought that organizations are systems in which all parts are interrelated and any change to one part will influence the entirety. In a system the whole is not equal to the sum of the parts. Between a classical, or Newtonian, view of science and a systems view exist the following contrasts (Laszlo 1996, 10-12):

- In classical science nature is seen as a giant machine with replaceable parts. The systems sciences look at nature as an organism with irreplaceable elements.
- The classical worldview is atomistic and individualistic; the systems view sees connections and communication between people and between people and nature.
- The classical worldview is materialistic, i.e. all things are measurable material entities; the systems view sees matter as a configuration of energies that flow and interact, allowing for probabilistic processes, self-creativity and unpredictability.
- A classical everyday disposition is of the type "compete-to-win"; in systems a "win-win" situation (Hoover 2002, 165) can be achieved through communication and information.
- Classical views lead to greater and greater use of energy, raw materials and other resources. The systems view looks for sustainable development through flexibility and accommodation among cooperative and interactive parts.
- The classical worldview takes a western perspective. The holistic, systemic vision includes a diversity of equally valid human cultures and societies.

Systems theory provide a means of exploring items in terms of their internal connectivities and their external relationships with their surroundings. The educational context can be viewed as a complex system in which a multitude of forces interact in complex, self-organizing ways,

thereby creating changes and patterns that are part predictable, part unpredictable.

2.2 Aspects on systems

General systems theory focuses on recurring patterns in various systems of differing size and substance. Von Bertalanffy (1968, 95) reacted against the atomistic, reductionism approach of Newtonian science and attempted to take entireties as the unit of analysis. He emphasized that real systems are open to and interact with their environments, and that they can acquire qualitatively new properties. This results in continual evolution of the system. Rather than reducing an entity to the properties of its parts or elements, general systems theory focuses on the arrangement of and relations between the parts that connect them into a whole. This particular organization determines a system, which is independent of the concrete substance of the elements. Thus, the same general concepts and principles of organization underlie the different disciplines. (Pearce 2002; Bertalanffy von 1968)

Just like the general relativity theory by Einstein the general systems theory can never be conclusively developed.[8] However, the approach has given rise to a number of concepts that supply a new outlook better equipped to cope with accelerating historical change. Thinking takes place in terms of connections within complexities. Particular phenomena are regarded as symptoms of the state of the system. Attention is paid to the process by which systems maintain themselves. Relationship among parts and wholes at various levels obey different organizational principles. Emergent properties develop when a certain level of complexity is reached. The same structures appear in vastly different systems. Systems thinking is a form of cross-disciplinary thought which makes it possible for members of many disciplines to communicate with each other in

8 A falsification of inductive universal theories is always possible (see Popper 1972). Newtonian mechanics has been falsified in modern physics. The possibility of falsification implies that no conclusive answers can be given, for example in science instruction.

a language which all can understand. (Pearce 2002; Scaruffi 1998; Bertalanffy von 1968; Einstein 1954)

The world can mostly be viewed as nonlinear. Originally the science of nonlinear dynamics was called the chaos theory because unpredictable solutions to problems emerged. The chaos theory (Lorenz 2001, 4) explores how systems change. Chaotic systems are sensitive to initial conditions. As a result of this sensitivity, the behavior of systems that exhibit chaos appears to be random, even though a model of the system is deterministic in the sense that it is well defined and contains no random parameters. Due to minimal inaccuracy in measurements the prediction of the system's motion goes wrong in the long term. While remaining deterministic the system's behavior is unpredictable and contains an infinite amount of internal details. It becomes impossible to model in any traditional way. (Lorenz 2001, 7-12; Scaruffi 1998)

The evolution of a system in time can be described with help of the concept "phase space".[9] The ordinary space has three dimensions (width, height, depth) but we can think of spaces with any number of dimensions. A useful abstraction is that of a space with six dimensions, three of which are the usual spatial ones. The other three are the components of velocity along those spatial dimensions. In this 6-dimensional phase space a point represents both the position and the motion of the system. Some special sort of shape in phase space represents the evolution of a system. Every such physical form is represented by a mathematical quantity called attractor. "The states of any system that do occur again and again, or are approximated again and again, more and more closely, therefore belong to a rather restricted set. This is the set of attractors." (Lorenz 2001, 41) The shapes that chaotic systems produce in phase space are called hidden or strange attractors. The system will develop towards the kinds of state described by the points in the phase space that lie within them. (Scaruffi 1998)

Complex systems undergo transformations; they make phase transitions. At the transition from chaos to order and back, at the edge of chaos, the system is still stable enough to keep information and unstable enough

9 This concept is well known for example from particle and nuclear physics.

to dissipate it. Order and chaos are in a special kind of balance. There is enough chaos for novelty and creativity, but also enough order for consistency and patterns to endure. The system is adaptable, it can learn. (Scaruffi 1998)

A cybernetic system is one that learns on the basis of feedback (Ashby 1956, 53-55; Pearce 2002). A cybernetic system is open to energy but closed to information and control (Ashby 1956, 4). Dissipation of energy in such a system may cause new instabilities and transformations into new structures of increased complexity. Self-organization is the spontaneous emergence of ordered structure and behavior in open systems that are in a state far from equilibrium and are described mathematically by nonlinear equations. In second order cybernetics the observer is part of the studied system and might change the system by observing it.

A central theme in systems thinking of the second order is that of circularity. Individual thinkers are themselves included in a circularity, maybe the circularity of their family or that of their society and culture. There will be a fundamental change in how teaching, learning, organizational management, even communication and relationships in the daily life is perceived. Objectivity derives from shared agreement about meaning and information or knowledge is an attribute to interaction. If one considers oneself to be a participant actor of the give and take in the circularity of human relations, one can only tell oneself how to think and act (Foerster 1995). Cybernetics addresses cognition, adaptation and understanding, issues that most other systems scientists are not so concerned with.

The second order cybernetic science contains a theory of constructivism. Through experiences an observer constructs an image of the world. She can never be certain that her views appropriately pattern the world as it is. It is reasonable to assume that others will construct descriptions of their experiences, which necessarily will be different in some respects. This view of knowledge supports a democratic perspective and a tolerant ethics. (Umpleby and Dent 1999, 79-103)

When a complex, nonlinear system becomes stressed or perturbed, the system becomes unstable. The further it comes from equilibrium, the

more unstable it will be. Humans and human organizations experience such a phenomenon of instability as anxiety, fear and stress. (See also Heidegger 1927, 140, 184) The system may correct its state in order to reach equilibrium, but these corrections are linear feedback processes. If these adjustments are not successful, the perturbation will take the system to a decision point, a critical choice. There may be many possible options. The future becomes unpredictable. But the possibilities are constrained by previous decisions that have led to this point. (See also Heidegger 1927, 144,145) A new self-organization is the result of this second order nonlinear process, one that may lead to increased complexity. (Rocha 1996)

2.3 Constructivism in systems theory

Constructivist psychologies are concerned with the questions how people know and what they know. Constructivism involves the active modification of thoughts, ideas, and understandings as the result of experiences that occur within a socio-cultural context. Thus the process of knowledge and understanding is social, inductive, hermeneutic, and qualitative (Sexton 1997, 8). Chiari and Nuzzo (1996) argue that the term constructivism should be reserved for those approaches that try to overcome the realism-idealism dichotomy (see also Kant 1990, 196), and distinguish two broad categories of constructivism - epistemological and hermeneutic. Epistemological constructivists believe that there can be many equally legitimate constructions of one external reality, whereas hermeneutic constructivists share a view of knowledge as interpretation. Von Glasersfeld's radical constructivism (Matthews 1994, 138) represents epistemological constructivism, whereas Maturana's and Varela's work (1980) provides a framework for interaction inside social domains using language and creating knowledge.

Different explanatory perspectives supply different ways of validating experience. Von Glasersfeld emphasizes the ability of human beings to use their understandings to adapt to a world that is not directly knowable. Human perception is adaptive. Adaptation improves the organism's equilibrium. However, people are only able to know when

the constructions of events fail (see also Heidegger 1927, 210; Gadamer 1975, 350). The failure of one's internalised mental scheme leads to accommodation of new knowledge. People remain in isolation as knowing beings even as they partake and adapt in social interactions.

Maturana and Varela (1980) think that no independent reality exists but that each individual literally creates her own world. According to Raskin (2002) their views of constructivism contain features of hermeneutic knowledge creation. Central to Maturana's and Varela's work is the self-sustaining development of organic systems. They see a living system as cognitively closed.

Features of the world that we each experience and construct activate changes in our structural dynamics. Our experiences are always our and never unmediated. Further on, if we define human agency as the carrying out of mental processes, this definition may apply not only to individuals, but also to groups functioning on an intermental plane (Wertsch, Tulviste, and Hagstrom 1993, 342).

2.4 Systems thinking

When faced with a problem, we instinctively focus upon close-by solutions, i.e. solutions that produce improvements in a short time span. However, short term improvements often involve significant long term costs. The achieved feedback may be misleading. It may be reinforced with many small changes building on top of each other. To recognize problems with such amplifying feedback and to understand delays, which make the consequences of change occur gradually, is important in the long term. (Senge 1990, 92)

Four steps can be used to describe a method of systems thinking and the systems dynamics (anon a). First the problem has to be formulated. The problem is described by focusing on patterns and their behavior over time and drawing graphs of time-dependence. It is important to look for reasons for the problem in the system itself. External reasons are mostly out of control. The overall tendencies of the system tell more than

many small details. Secondly dynamic hypotheses or models that could explain the problem are formulated. Activities that define the process under investigation are questioned and the structure of the process is described. Closed loop thinking is a usable ongoing interdependent process. Estimation of important unmeasurable variables should be included. These could be tested for example through simulation or with the help of pilot projects or test samples. Then the model should be tested to be certain that it reproduces the behavior seen in the real world. Alternative models should also be tested. Only when the situation is thoroughly understood changes can be implemented.

2.5 Teams as systems

A social system is according to Ackoff and Emery (1972, 215) a system whose elements are purposeful individuals. Such a system is dynamic and generally assumed to be open. The relationship between the system and its members causes the feature that the system is either more or less than the sum of its parts. Organization of the system is realized through the potentiality to make choices with respect not only to one's own purposes but also to the purposes of others (Ackoff and Emery 1972, 219).

Maturana (1980) considers social systems as emergent from the interactivity of their members. Their character depends on the specific interactions among their members. Members and system influence and change each other through these ongoing interactions. Members may be part of many social systems, like teams or clubs, but within each one they function as being in a distinct domain of interaction. In the different settings they may exhibit different role-characteristics.

A team may be defined as a group that constitutes a system; its parts interrelate and its members share a common goal. A popular developmental model of a team is the forming, storming, norming, performing model. Each phase corresponds to a stage in the life cycle of the team. Another approach is the analysis of the team's structural patterns like positional roles or processes. A team has an input, which might be information, energy or resources. The system acts to transform

the energy from the input into the output. This transformation process varies due to internal and external factors. Identification of such factors is important in attempting to maximize the performance of the team. (Stamatis 2002)

2.6 Schools as systems

School systems are so complex and expansive that it is often difficult to be certain whether one truly considers all the elements of the system when making changes. Thinking systematically requires several shifts in perception, which in turn lead to different ways to teach and different ways to organize the school community. Shifts in perception can lead from curricula based on single subjects to integrated curricula, from parts to the whole. This implies a shift from analytical thinking to contextual thinking. The nature and quality of what students learn is strongly affected by the culture of the school. In the systems view the matters of study are networks of relationships. Schools that adopt this perspective are likely to emphasize cooperative processes and decision-making by consensus. The process of making decisions is often as important as the decisions themselves. Certain patterns of relationships appear again and again. Understanding how a pattern works in one system helps to understand other systems that show the same pattern. (Senge et al. 2000, 77)

Despite the pyramid-type structure often ascribed to schools they tend to operate much more like living systems. They function like dynamic and complex webs of interactive loops. A typical school system has several layers, each of which helps to ensure the success of the next layer. Each level selects, plans, organizes, and makes provisions. Each level also studies, reflects and learns, refines activities, improves achievements, and informs adjacent levels. (Senge et al. 2000, 393; Doolittle 2001)

Students use systems thinking to clarify their understanding of complex systems. They interact with each other and explore thoughts, perceptions, and mental models. When students make their thinking visible, teachers can easily identify different ways of understanding subject content. A

systems thinking helps students to make connections between curricular areas and authentic life experiences. Understanding of system structures enables students to see similarities between seemingly different systems. This helps students to find new and varied perspectives when solving problems. They may then question and challenge seemingly obvious solutions to complex problems and they can reach an understanding of their own mental models. Many students thus develop increased motivation and self-esteem. (Senge et al. 2000, 176; Doolittle 2001)

In this chapter I have given a short review of those features of systems theory that are of interest when the school community is viewed as a system. First I describe the worldview of systems theory. Then different aspects on systems, such as creativity, learning, and circularity are discussed. The connection of constructivism to systems theory is of importance for the socio-cultural aspect on learning. Systems thinking forms the ground for Senge's (1990,92) organizational theory, which will be discussed in the next chapter. My study concerns school as a learning community and teams in school. Thus in the end I place these into the context of systems. In the next chapter I will discuss the school as a learning organization. According to Senge (1990, 3) learning organizations are "organizations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning to see the whole together".

3 Perspective on the nature of learning

At the beginning of modern time, when big scientific discoveries were made, philosophers looked for a firm foundation of thought in two distinct directions. Between on the one side a rationality of comprehension and reason and on the other side an empiricism grounded in experience a conflict developed.

Descartes aimed to provide a unified framework for understanding the universe. He wanted to construct a coherent theory of the world and man's place within it. In order to achieve this he had to test all his former believes with radical scrutiny. His "method of doubt" involved applying sceptical techniques, which had been revived in the sixteenth century. He pointed out that the senses often are unreliable and thus not trustworthy. On the other hand there is an inescapable logical limit to scepticism about what exists. The existence of thinking itself cannot be denied. Once this was established Descartes systematically attempted to reconstruct a reliable body of knowledge. His construction proceeded from an awareness of self to knowledge of the external world. (Descartes 1637, 82)

The thinking of Descartes achieved a far-reaching significance. Thinking man doubts, understands, comprehends, accepts and forbids, imagines and experiences. Knowledge is only that what can be comprehended with the help of reason. As true one can consider only such statements that reason can conceive clearly and unobscured, without any suspicion or doubt. Yet Descartes admits that also clear and evident observations can be doubted.

The empiric theory of knowledge developed by Locke is grounded in simple ideas founded on sensations and reflection. These ideas include thinking and intention. The mind, being originally empty (tabula rasa), cannot create or eliminate sensations. Strictly speaking man recognizes only his own perceptions. Solely words and language make meaningfulness and understanding between humans possible. Hereby universal concepts are created in abstraction of experienced needs.

In Immanuel Kant the new trends that had begun with rationalism and empiricism were subsumed to a new theory of knowledge. Kant (1990, 196) succeeded to avoid a sceptic theory of knowledge by accepting transcendental idealism. Accordingly comprehension of space and time are features of human senses. Objects in time and space depend on sensations and understanding, and are directly available for cognition. Objects in time and space constitute that part of the world that is composed of phenomena about which knowledge is possible. This knowledge has been formed and classified by using concepts that are founded on individual understanding and sensations. The world as such is unknowable.

Subsequent interpreters and developers of Kant's thoughts see concepts as being dependent on language and society. Devitt (1991, 235) calls this theory constructivism and describes its contents in the following way: The one and only independent reality is unreachable to the knowledge and language of man. The known world is partly constructed with the help of concepts. These concepts differ in linguistic, social and scientific respects in different communities. Each such world exists only in relation to those concepts that the community applies. (See also Devitt and Sterelny 1987, 199-209)

Constructivism calls for us to rethink our current knowledge base with the purpose of understanding our connection with the larger culture (Vygotsky 1962). Thus the constructivist perspective commits us to multifaceted and contextually based change. We seek to learn about our own thinking. We are interested in finding ways to improve the world in which we live. We care about ourselves and for the world (Heidegger 1927, 57, 122). This care includes a willingness to expand our beliefs, to shift the borders of our thoughts and feelings in order to help others.

The constructive theory of learning has two distinct branches. The first, psychological constructivism, is based on Piaget's understanding of children's learning (Flavell 1963). It rests on two main principles: Firstly, knowledge cannot be achieved passively but is actively constructed. Learning consists of the construction of an individual intellectual scheme, the development of an increasingly dense network of knowledge.

Secondly, the cognitive process is adaptable and serves as an organizer of the experimental world.

Von Glasersfeld, in his radical constructivism (1987, 109) combined with his insights from cybernetics, breaks with earlier convention and develops a theory in which knowledge is constructed solely of experiences. The experiencing individual forms the origin of all her knowledge structures. Knowledge is a self-organized cognitive process of the human brain; it is not aimed at a true image of the real world but at a viable organization of the world as it is experienced. According to von Glasersfeld "knowledge is not passively received but actively built up by the cognizing subject. The function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality" (Glasersfeld 1989, 162).

The second branch considers knowledge to be constructed through influence of non-individual social circumstances (Durkheim and Giddens 1972). Individual inner psychological mechanisms are ignored. According to this theory knowledge is a form of cognitive construction without direct connection to reality and truth. Thus we do not discover truths but we construct possible explanations for our experiences. Knowledge is created by man in a historical and cultural context and is not absolute.

Hermeneutic constructivists do not believe in the existence of an observer-independent reality. They describe knowledge as a product of the linguistic activity of a community of individuals.[7] Thus, there can be as many knowledge systems as there are groups discursively negotiating them. In hermeneutic approaches to constructivism, the roles of language, discourse, and communication become central in understanding how knowledge systems are developed and maintained. There are many forms of hermeneutic constructivism, but they all share a view of knowledge and truth as interpretation. This interpretation is historically founded rather than timeless, contextually verifiable rather than universally valid, and linguistically generated and socially negotiated rather than cognitively and individually produced. (Chiari and Nuzzo 1996, 174)

7 They apply an ontological perspective to cognizance.

Psychological constructivism has inspired different programs of educational reform. These suggestions for instruction radically differ from earlier teaching methods, which assumed that it is possible to directly transfer knowledge to the student. Constructivism presupposes that knowledge is composed and constructed. It is not transferred. Earlier knowledge is the foundation for learning. Beginning understanding is local and concrete. To build useful knowledge constructions is hard and asks for appropriate activities. Much of the learning takes place unconsciously. (Piaget 1970; Kitchener 1993; Glasersfeld von 1989; Chiari and Nuzzo 1996)

Except for as philosophy and epistemology, constructivism can also be used as giving guiding principles for a communication theory (Vygotsky 1986). If a message is sent or information is supplied without knowledge about the receiver, it is not possible to know how the communication is comprehended and it is impossible to interpret the answer unambiguously. From this point of view instruction is to be considered as reinforcement and continuation of the communication between teacher and learner as well as between learners and their peers. Merely a supplement of material, a presentation of a problem and a collection of answers do not constitute a communication sophisticated enough to achieve an effective process of learning.

3.1 Interaction

Learning without the experience of difference is an impossibility. In today's organizations, reaching global dimensions, communication and interaction with foreigners from different cultures is a daily matter. The first impression of a new acquaintance is formed with the help of experiences and the own personality. Exterior features, behavior and communication form the basis of the impression. Sometimes the first impression might be wrong. If the interaction is not broken, the field of experience will grow and a possibility of learning arises. Interaction skills can be learned. But the process might be slow. In interaction the main question is about how well one knows oneself and how well one can express this self.

Communication in a community usually is looked upon from two different perspectives. The aspect can be the individual's or that of the community. In the first case the communication skills and communicative knowledge of the individual are of interest, in the second case organizational communication strategies and principles. In the following the development of a dialogue between individuals in a system and of collaborative, contextual interactions in organizational systems will be analyzed.

3.1.1 Dialectic dialogue

Communication is a two-way process. There is a sender, the message to be sent, the channel through which the message should be sent, and a receiver. The roles of sender and receiver should be interchangeable. A symmetrical, interpersonal relationship between two individuals consists of dialogue. (Baker 2002a, 10; Hoover 2002, 22; Strömmer 1999, 219)

Personal identity develops as a result of the socialization process and interaction. Physical, psychological and social characteristics and skills are implemented in the individual as a result of the feedback that she becomes from others and as a result of her own experiences (Belbin 1993, 43, 77; Hoover 2002, 21). Personal identity forms the reference frame through which an individual interacts with the social environment. In order to develop an identity the individual needs an ideal picture of herself, as she would like to be. If this picture is close to her experienced identity, she feels self-confident and knows her own value. A person maintains her inner equilibrium by accepting primarily such feedback that corresponds to her experienced identity. (Simon 2004, 10-12, 31-34)

The process of communication is much more than spoken interactive messages (Hoover 2002, 30). Tacit communication (Nonaka and Takeuchi 1995, 59, 62) can be divided into communication by signs, by action, and by tools. The first category consists of symbols for the interpretation of which the eyesight is responsible. The sign language of the deaf mute, a smile, gestures, and shaking the head are examples from this category. Communication by action takes place with the help of

gestures that are not symbols of special meaning, for example standing up, moving restlessly, weeping, and making faces. Communication by tools includes for example impressions created by way of dressing, appearance, furniture, and other exterior interaction features. Tacit communication is culture dependent.

An individual usually shows her self-conception in her communication. She can be active, eager and partaking or she can be passive and hesitating. In conformity with this her communication makes a certain impression on those that listen to her. The listener must adjust her own communication style accordingly. Therefore she has to listen in a distinct and analytic way, she must interpret, explain and understand, and then adapt and apply what she learned to her own action. Both the speaker and the listener are helped by an open, questioning mind. One should question both one's own intentions and the understanding of the listener. (Baker 2002b, 111; Hoover 2002, 31)

The receiver might interpret the message in a way not intended by the sender. She looks for the meaning of the message using her earlier knowledge and her estimation of the situation. (Ricoeur 1976, 77-78) The message can also be unconsciously changed by the receiver to correspond to her expectations. Already the message sent can diverge from the sender's intentions. This can be on purpose or it can be unconsciously. Incomplete messages sometimes cause severe misunderstandings. The sender might assume that the receiver is able to read between the lines correctly, that she thinks in exactly the same way as the sender.

Opposing voices in search of truth, attempting to understand the world they share between them, include all senses, emotions and feelings in conversation. In order to understand the other the listener must try to enter into the mind of the speaker. To ask oneself how the opponent thinks, what she expects and desires, and to meet her on her own grounds are the premises for an edifying interaction. Continual dialogue between explicit and tacit knowledge drives the creation of new ideas and concepts. Conversation can catalyze visions and innovations for new development and learning. (Nonaka and Takeuchi 1995, 62)

In a dialogue the partakers move between speaking and listening. But also moments of silence are important. They can be experienced as an open door or invitation to move into conversation. They give possibilities to reflect over actions taken and things said so far (Baker 2002b, 101). There is a dialectical movement of action and reflection as the partakers move outward into the external world and inward into themselves. Reflections might cause recourse. As new ideas are grounded through the discursive process and questioned from different perspectives through the recursive process a spiral movement ensues. The partakers as individuals experience their relatedness. And the dialogue gets its character from the relationship between the partakers, which can be anything between authoritative and egalitarian. (Kolb, Baker and Jensen 2002, 60-65)

The results of such a dialogue are similar to the fusion of horizons that Gadamer (1975, 370) describes. Interpersonal communication reveals the world between people. What people create together is something that no one of them could have created alone. Also Vygotsky (1978) describing his zone of proximal development defines it as "a variety of internal developmental processes that are able to operate only when …[the individual] is interacting with people in his environment and in cooperation with his peers".

3.1.2 Collaborative, contextual interactions

Each organization has, or should have, its own values and its vision for the future. Depending on how well vision and values are internalized by employees these feel correspondingly committed to their employer. Therefore it is vital for the organization to inform employees about values held in honor and give employees the possibility to discuss and influence these. The visions, goals and strategies of an organization should be communicated to the employees in a clear and understandable way. Employees should be given the possibility to discuss and comment on visions and valued outcomes of performance. The visions of an organization change with time. Often visions are comprised into a brand like "Connecting people" used by Nokia. Strategy is the way the organization plans to reach its goals. It forms the frames for daily action. Employees should be well acquainted with, and committed to, the values

as well as the vision and strategy of the organization. (Hoover 2002, 55)

If employees do not agree with the visions and goals of the organization, a conflict arises (Hoover 2002, 156). This is substantive as long as it concerns the content. But it might develop to an affective conflict as personal characteristics become involved. The effects of a conflict can be both positive and negative. Conflict breeds social interaction and increases involvement. It might also result in higher quality solutions. However, this implies that the opponents stay calm and listen to one another. If they become anxious they tend to reinforce the negative reactions, which at the beginning prompted the exchange of opinions. If one party then withdraws, both parties will loose. If one party accommodates or one party forces his will through, there will be a looser and a winner. If a compromise is reached both parties both win and loose. Only if collaboration is reached, both parties win. (Argyris 1992, 254-255; Hoover 2002, 165)

A good organizational climate (Strömmer 1999, 63) depends to a high degree on management and leadership. Positive feedback on work performance and an attitude to errors and mistakes that promotes learning increases the well-being and a feeling of congeniality in the work group. Only someone who has positive attitudes towards the other and shows him appreciation can give genuine feedback. And one cannot accept feedback in the right way if one cannot feel grateful for getting it. Gratefulness creates an encounter between individuals and thus a positive feedback culture develops. Feedback that only takes into account results achieved might sometimes exert pressure on the employee. Contentedness among employees has a direct influence on the effectiveness of the organization. (Hoover 2002, 97)

The present continuous development and change of knowledge and skills demands in organizations request that employees are supported and encouraged to continuously learn to manage in new situations (London and Mone 1999, 140). Policies that emphasize employee development exist in most organizations. The employee is asked to discuss her work, possibilities of performance, and development of tasks with her works

manager. Often this discussion is used to give feedback and assess the work of the employee. This can influence the discussion in the wrong direction. If the employee is anxious and expects negative feedback, she will not be able to accept suggestions for future learning and performance in a reflective and positive way. The manager should find the employee's zone of proximal development (Vygotsky 1978) and in discussion with her plan the directions and contents of her learning.

3.2 School as a communicative system

As individuals we are always involved in communication with our environment. Only in death our communication expires. Communication includes speaking, listening, and wordless expressing with the help of, for instance, gestures or countenances. Our way of communication is dependent on the culture of which we are a part and on our social surroundings. A primary task of communication is to build understanding between people. Thereby it is not only of importance that we express our own opinions, but we should also listen to others and ask about the views they have (Wyss-Flamm 2002, 140, 150-158). In order to understand them as well as possible we must interpret and explain the statements of others. We have to find the actual core in the messages we receive. If we concentrate on listening, speaking comes of it self. (Hoover 2002, 20-23)

Culture is in itself communication (Wyss-Flamm 2002, 141). An individual can belong to many cultures, which can be in contradiction to each other. The role of a teenager at home with the family, in the gang of youths, or at school might be quite different. Only by learning to know and understand oneself it is possible to overcome contradictions in cultures. The strength of our own personality gives us the power to see problems from different perspectives, from the point of view of different cultures. Therefore we must learn to listen and understand. (Hoover 2002, 31)

At school, communication between students and teachers form the foundation for learning and teaching. Lately interaction between students

and teachers and also between students in groups of students has been studied with increasing interest. The importance of authentic discussions that allow students to speculate and hypothesize is emphasized. (Myhill and Brackley 2004) However, communication between teachers and the influence of discourse and conversation on teaching methods, the atmosphere in teachers' rooms and learning among teachers are almost neglected as objects for investigation.

Each school has its visions and values, grounded on individual visions and values inside the school community, which are presented at least once a year at school-leaving time. At this opportunity sometimes also the strategies and norms of the school are presented. Usually executive boards lay the foundation for strategies and norms, and these are then discussed at teachers' conferences. Teachers' conferences form the main communicative board at school. This board is the only official one where any teacher can ask for the word and present her ideas and opinions concerning work at school.

Conversation in the teachers' room is seldom connected to strategies and visions. Often only superficial politeness is pronounced, interrupted by short exchanges of routine information. The breaks between lessons are too short to allow any serious discussions. If some relations arise, this will happen between teachers teaching the same subject. But also here a deeper discussion of principles and methods of teaching are rare.

3.2.1 The principal's communicative role

The principal's presence and availability to teachers and staff at school is important. She must have time to listen to and talk with teachers. Only so a sensitiveness to and understanding of the atmosphere and situation in the teachers' community may develop. The principal's conversation with teachers enables these to position their own role in a larger educative context. They may see their work as a part of the school organization. Face to face communication increases trust and commitment to the task among teachers. (Juholin 1999, 52, 106)

Leadership requires sensitivity to followers' needs. The principal is task leader, social leader and provider of information and tension releaser. She must define the task in front of her and her teachers, decide the route of action required, recognize expectations and dissatisfaction in the teachers' community, reflect over goals, visions and values to be held in honor, and think about empowerment of teachers and other personnel. Her role and the way she communicates with her staff shape the atmosphere of the school community. The degree to which colleagues like one another and want to work together defines the cohesion of the community. This is expressed through similarities in attitude, believes and values, trust, inside jokes, traditions, common endurance in difficult situations, and so on. The principal invites others to share in defining and building a common vision of the future. As manager she has the responsibility of locating and providing supportive knowledge and materials so that staff can perform their work at a higher level of excellence. Her success is defined by the performance of the followers. (Trenholm and Jensen 2004, 343)

3.2.2 Supervisory communication and feedback

It is important for anyone to get feedback on work activities and actions undertaken. At school one important task of the principal is to give teachers individual feedback at least once a year. But both positive and negative feedback can be given always when there is an occasion. It is important to comment on actions as quickly as possible. Especially negative feedback should be given in connection with positive and in a constructive way. Negative feedback must always be given privately. (London and Mone 1999, 135-137)

At the yearly communicative assessment of work progress the principal privately discusses with each teacher in turn. She informs about expectations on the teacher's work, assesses the progress, and defines the role of the teacher in the community. A prior aim is to find the teacher's developmental possibilities and potentials. The principal must feel secure in her own relationship to her supervisors in order to be believable during this discussion. She has to be well informed about the expectations and visions of the board of education. Thus a concrete plan for the teacher's

future actions and progress can be developed. This can include future education and learning in special fields of interest, development of teaching methods, and involvement in activities connected to the teaching process at school. When the principal gives feedback, she should invite the teacher to express her feedback to the principal in return. (Hoover 2002, 32)

There are also difficult things to be discussed between principal and teacher. Conflicts between teachers can sometimes become so pronounced that the principal has to intervene. It is then important to clarify the background and reasons for the conflict. Also future choices and results of destructive processes must be discussed. Above all that a destructive problematic spiral is allowed to arise has to be avoided. (Hoover 2002, 166-170)

3.2.3 Communication strategy

Strategy means a conscious choice of modes of action in order to reach central goals. The school community defines the impression it wants to give to the surrounding society. This can be of a certain reputation or a special atmosphere. The operative planning suggests means to reach these goals (Lord and Smith 1999, 195). A work group starts to develop a picture of the school community as it would like to appear in the eyes of its stakeholders. The work starts from earlier definitions, like tasks, goals and strategies. The group works with the original strategic communication concept, first by itself, then in the school community, and, maybe, with outside collaborative groups. When the communication strategy is defined, it will be tested in central stakeholder units. Thus one can find out to what extent the desired picture of the school community already exists. The leaders have the difficult task to decide about the profile to be aimed at and about goals to achieve. (Campbell 1999, 406)

In each grade at lower secondary school an annual meeting between parents and the teacher in charge of the class is stipulated. At these meetings general problems such as unrest or conflicts in the class and common interests like camp school are discussed. Parents' representatives are chosen. Their task is to represent parents in discussions with the

directorate, parents' organizations and the principal. Further on there is at least one day of open doors, when parents and relatives may take part in the work at school, visit lectures, and get information about general problems and norms and the values of the school. (Juholin 2003, 27, 36)

As the principal's help a group of four to six teachers, among them the vice principal and some stationary members, but also at least one teachers' representative chosen for a one year period, meet regularly. This group has a central role in introducing changes and creating strategies for the future. The leaders must present the content in such a way that teachers understand the necessity of change and feel committed to the project. It is also important that changes can be discussed and commonly agreed upon. (Juholin 2003, 33)

At school obligatory meetings and conferences are held regularly. Primarily actual teaching situations and tasks are on the agenda. Students' assessments are evaluated. Students with special needs and necessary steps to handle these needs are discussed. Also cultural programs within the school are suggested and discussed. Conferences are occasions for face-to-face discussion and interactive communication. However, teachers often feel that conferences are unnecessary and time consuming. Teachers are not motivated to beforehand think about problems to be discussed or about statements to be made. An open atmosphere and active questioning are almost impossible to achieve as long as conferences are held after school when everyone is tired and wants to go home. The principal as chairman goes through what stands on the agenda and keeps the timetable. Her task is very difficult. Maybe a rotating system for being chairman could help. Also, if groups of teachers had prepared some questions beforehand and presented the result of their work, the decisions could more easily be taken. Such group work can be creative and bring truly new ideas. (Hoover 2002, 68)

3.2.4 Good communication

Many features should be taken into account in school community communication. The first and maybe most important is that the school has

succeeded in acquiring its own profile. A school needs to be appreciated in order to appeal to students and parents. If it has a well-known profile and motivated teachers, it can be attractive to students with these special interests and thus can develop in this direction also in the future. The school has a reputation. Values of the school are recognizable in the educative results. It can, for example, be known as a school supplying excellent education in music or in mathematics. This can be done only with the help of teachers excellent at teaching their subjects, principals selecting such teachers, and boards of education supplying necessary resources. Then it is up to the students to create the profile. Secondly, the school should supply enough information. Here not only profile but also other attractive features of the school are of importance. Information can be available on the home page of the school, but it is very important to appear in media, too. The press should always be informed when students have performed excellently in larger contexts or when some occasion of common interest takes place at school. At school an ongoing dialogue with and listening to students, teachers, and parents must take place. Only so involved persons will feel content and committed to their school. Interaction between school and social surroundings is also important. Satisfactory communication between school and society and inside the school community forms the foundation for empowerment of both teachers and students. After all, school educates its students for a life in the society. Thus educational directions are of interest for the society. Interactions on all levels, face-to-face, electronic or printed, and distribution of annual reports and statistics, help to integrate school in society. (Juholin 2003, 36)

Collaboration with industry and companies in the environment not only motivates students, but can also help them to find a future profession. Communication should continuously be scanned for satisfaction, both inside the school and outside. This can be done with the help of a questionnaire. However, the task of making the right sort of questions is not easy and might request the skills of a professional investigator (Cohen, Manion and Morrison 2000, 248).

3.3 Conflicts in the school

Communication during conflicts requires openness. Fear of the consequences of speaking often silences a party's opinion. Criticism should be focused on ideas, not on people. Word choices matter and they may cause the conflict to escalate (Baker 2002b, 112). Open-ended problems give possibilities to present many different perspectives and so the yes or no dichotomy is avoided (Hoover 2002, 169).

Teachers often experience loneliness in their work. They are mostly alone with their class, without the possibility to exchange more than superficial remarks with colleagues. The breaks are short and filled with preparation for the next lesson; maybe the teacher then has a task as custodian in corridors and on playgrounds. As long as the principal is not confronted with concrete problems she assumes that all is well in the classroom. A new teacher is often afraid of asking for help, because this would mean that she is unable to keep order in her class. Especially this is true if the students already have the upper hand. One cannot easily tell the principal that the classroom situation is chaotic.

3.3.1 Intrapersonal conflicts

Emotional conflicts are usual in the classroom. The teacher must try to be objective towards her students. This is often very difficult. There is the silent, withdrawn little girl and the boisterous boy that cannot be left without attention for a moment. How to show them equally much devotion? There is one student studying very hard to get good notes and another one not caring about learning at all but achieving very good notes in tests. How to assess them justly? Many teachers feel a heavy stress at the time when notes should be given.

Nowadays there is much talk about the necessity to change school culture and teaching procedures. Some elder teachers find it difficult to change. They have been teaching in an authoritative way for years, with good results, and now this would not be good anymore. Some schools silently resist the change. Here a young teacher with innovative ideas about teaching comes into a procedural conflict (Hoover 2002, 158).

She has three ways to choose between. She can try to follow her own feelings and develop a new teaching procedure and culture at the school. This is a very difficult task that can lead to interpersonal, intragroup and intergroup conflicts. But being successful the teacher will develop pleasure and commitment to her work. She can also try to adapt herself to the teaching procedure used in the school. If she succeeds, the teacher will feel contentment with her work. The third possibility is to try to escape from the situation. Maybe it is possible to find a position in another school with a more agreeable culture. (Hoover 2002, 161)

3.3.2 Interpersonal conflicts

Reasons for interpersonal conflicts can be found in communication problems or in different cultures of action and work. Problematic and ambiguous work conditions might also influence relationships.

Disturbances in communication arise through false interpretation. The choice of words may not agree with the tacit communication. The receiver of a message interprets it according to her own earlier experiences or expectances. Thus she might accordingly decide things and events instead of asking the sender of the message about a confirmation of her intentions. The way of action or behavior can under some circumstances lead to conflicts. For example an elderly colleague might become insulted by the behavior of a young newcomer who may want to introduce new teaching methods. The elder colleague thinks that what has worked until now is good also in the future. Competition and envy between individuals will also lead to bad relations. Under conditions of stress these problems become more pronounced. (Vartia 2003, 15) Although the ultimate reason for most conflicts can be found in factual situations, feelings of antipathy and distrust play an important role. An individual cannot judge another's feelings or moralize over them. She only has to recognize and respect the opinions of the other.

Interpersonal conflicts occur whenever goals are blocked. Showing too much aggression might be destructive, although a fight is not always a bad thing. But fights should be delivered immediately when conflict occurs and not be postponed. If the individual chooses to escape conflict,

this will in any case infect her relations to the colleague. Saved grievances are like an infected wound; one day it will burst and spread its pus. (Trenholm and Jensen 2004, 323)

Conflicts can also be looked upon as positive features. They show the interdependence of individuals. If the individuals would be totally independent, there would be no reason for conflict. The fight also shows that the individuals care about each other. There are problems that need to be solved and mutual needs and expectations to consider. If the conflict is resolved, an increased cohesion is the result. (Trenholm and Jensen 2004, 322)

Conflict shows that there is a need for change. It provides a possibility to become more adaptable. In solving the conflict creativity arises. New ways of relating to each other are found. However, communication during conflict has to follow certain rules. One should stand for what one says. Never push the responsibility on someone else. One should allow oneself to be angry, to show one's feelings. But it is not necessary to insult the other. It is important to be clear and specific about what one finds is wrong. And the tacit messages should agree with the spoken. (Trenholm and Jensen 2004, 324)

3.3.3 Intragroup conflicts

Norms and strategies in a group, decisions made about rules and measures as well as personal relationships inside the group are the most common reasons for intragroup conflicts. According to the background conflicts can be divided into such that concern power, advantage, goals or values. Mostly also communication problems and misunderstandings hover in the settings. Very few causes of conflicts can be situated on a scale reaching from right to wrong. They can usually be looked upon from different perspectives. Each individual examines the problem using her own aspects. Different aspects may be equally good or bad. An individual may learn to see the value of joining one perspective with that of the other in an innovative way. (Wyss-Flamm 2002, 156)

Change might be a result of conflict, but can also create conflict. Change is a threat to security, because one has to give up what one is accustomed to. Most people try to resist change. (Argyris 1992, 123) This is true if the intervention comes from outside the group as well as if it comes from inside. It is important that information about change comes as soon as possible and in a face-to-face manner. Then no rumors have time to develop and the concerned individual has a possibility to ask questions and express her needs and fears (Argyris 1992, 70).

In the school world the concept mobbing is well known. The concept is used to describe the harassment, bullying, insulting or exclusion of some individual in a social context. Then mostly mobbing among students is considered. However, also teachers mob each other. This phenomenon is connected both to superficial social contacts between the teachers and to stress, envy and frustration arising between overcharged colleagues. The atmosphere is intolerable. Then one has to find some scapegoat. This is systematically bullied over weeks. (Zapf 1999, Vartia 2003, 12) The scapegoat was perhaps from the beginning on an equal footing with her colleagues. However, the systematic mobbing drives her to desperation. Especially tacit mobbing behavior is very difficult to document.

Mobbing is a criminal act and therefore must not appear at workplaces. The reasons for mobbing should be investigated and cleared away whenever it is possible. If stress and bad working conditions can be a reason, improvement in the atmosphere at the work place is asked for. The social climate can be considerably improved in interaction and communication. Individuals in a group may be very different and it can be difficult to accept and respect people that one does not agree with at all. But one should not forget that heterogeneity in a group also means different perspectives, new knowledge and new challenges. If someone can offer new tools with which to change one's way of action, why should an individual not accept this, especially when she does not loose in personal importance? (Hoover 2002, 165, 168)

Interaction enables people to build communities and to commit themselves to each other. One such community is the workplace. A sense of belonging and the concrete experience of trust and tolerance

that can be involved bring great benefits to people. The more important the relationships are the more probable it is that conflicts are solved in an accommodating or a problem-solving style. The accommodating style is usually chosen when the individual's personal goal is not of high importance. The problem-solving style assumes that conflicts are natural and can be solved with the help of openness, rationality and cooperation.

3.3.4 Intergroup conflicts

Opposition, disagreements and disputes between groups of teachers can cause conflicts in the school. Groups might start focusing only on their own interests. For example a strong group of language teachers might want to develop the language laboratory without taking into account that the science laboratory is very rudimentary. Such a horizontal conflict arises from incompatible goals or attitudes. A vertical conflict might arise as a result of superiors' attempts to over-control. The reason can be goal conflict or cognitive conflict due to sparse communication and negotiation. Diversity based conflicts at school usually arise between teachers of the old school and young reform-interested teachers.

A confrontation between groups can enhance and benefit the performance of the organization. Without such functional conflicts there is little hope for change and development in the organization. On the other hand such conflicts, if they are not solved, hinder the achievement of organizational goals. Then the performance of the school will be weakened. (Argyris 1992, 122)

3.4 Diffusion of knowledge in teachers' community

At school not only students learn. Teachers also deepen the knowledge of their subjects and develop their teaching methods. There are special days, when students have free time and teachers devote themselves to learning. Usually they then take part in some course organized especially for this purpose. But teachers also learn from colleagues or they themselves do research to improve their teaching.

There are large amounts of knowledge hidden in teachers' communities at schools. But rather seldom one hears that a group of teachers has worked on some project and developed new and inspiring ways of teaching or of assessment. These new ideas only slowly diffuse to other groups of teachers. It seems that the wheel has to be invented anew at each school. The communication between schools and especially between groups of teachers seems to be next to nonexistent.

The tasks of communication can be defined as supplying information, keeping a dialogue going, and constructing visions, strategies and values (Juholin 1999, 17-21, 25). Communication is a means to deliver and receive knowledge. Interpreted information is knowledge in accordance with Plato's definition: "Knowledge is well founded, true belief".

Communication channels and their use form part of the strategy. The channels are part of the larger communication system, to which the information content and norms and agreements according to which the system works also belong. The channels can be divided into three categories depending on whether the communication takes place face-to-face, as printed messages or as electronic information. In everyday communication face-to-face interaction is most common. There are meetings and ad hoc conferences, discussions and other non-official occasions, where teachers can exchange opinions face-to-face and immediately react on the messages. Written daily information is used for short notifications, be it electronic or hand written, for example to inform about students that are absent, excursions or meetings. (Juholin 1999, 26)

In communication the increase of knowledge in the teachers' community is most important. Also the modification and acceptance of the visions and values of the school are important results of daily discussions. There should be adjustable goals for communication in the same way as there are goals for other activities. However, although information is conveyed between teachers and the principal, teachers show little interest in each other's work. Principals might suggest methods to increase such communication, but with little success.

Looking back some ten years one can see a difference in interaction between teachers. In comparison with earlier, teachers work with open doors to a much higher degree today. The use of companion teachers has also increased. This means that there are two teachers in the classroom during a lecture. Because the number of students in the groups has increased lately and integration of students with special needs is common, most teachers welcome this possibility to share the responsibility. Here only economic reasons intervene with increased interaction.

Teachers could take a bigger responsibility for developing and changing school. Increased contacts between different groups of teachers, also representing different schools, would then be necessary. Often teachers have ideas about how to improve their work, but they do not find the occasion or courage to discuss these ideas (Eppler 2004). They expect little interest from other teachers. They also feel shy and unimportant. Such knots could be opened during a nice chat with colleagues. (Lindström 1994, 33) It is therefore a step in the right direction to organize teams of teachers working with the same or similar subjects. It can still happen that one teacher has introduced and used a teaching method in her classes during the last ten years and that her colleague, working in the classroom next door and teaching the same subject, is quite unaware of this. Interaction between teachers teaching different subjects is also needed. According to the curriculum (anon. b) integration between different subjects should be used in order to give students a holistic view of the content of the lessons. Some seminar now and then might not be enough to give teachers the right impulses. It would, however, be important that teachers could see their work as part of a larger context. Hindrances for knowledge to move, change and get internalized can be for example a wish to keep one's knowledge to oneself as a sort of security, conflicts in communication or missing interaction skills. (Leppänen 1994, 69-72)

The results of teachers' work to improve teaching should become acknowledged by the school and the board of education. Teachers should be invited to tell about their experiences at meetings and conferences and to publish their results in journals for that purpose. Universities and teacher education institutes should upkeep regular contacts to schools. It is not enough that teacher students send questionnaires to

schools in order to get material for their graduate works. Researchers of education and teachers must come closer together if a mutually profitable communication and information exchange is to occur. Steps in this direction are undertaken. Conferences for both researchers of education and teachers have been organized lately (see e.g. anon. c). However, presentations by teachers are still rare.

Information about interesting developments in teaching and education at schools in foreign countries exists. For example lately the Hungarian way of teaching mathematics has been of interest (Näätänen 2001). In Finland many teachers devote themselves to laboratory mathematics and problem solving (Ikäheimo, Järvinen, Kairavuo, Lampinen, and Voutilainen 2003). There are conferences for mathematics teachers and education researchers in mathematics organized for example in Sweden (anon. d). These conferences are very popular. But they are also very big. Small meetings would be more profitable for teachers, who could then make personal contacts to researchers.

For diffusion of knowledge in the school community it seems that teachers must find courage and time to present their own thoughts and ideas. If one hour a week could be scheduled for obligatory chatting and coffee drinking in small groups, many grains of knowledge would already be sown. No intervention or outer disturbances should be allowed. A reason that occupational guidance and tutorships have become so popular in many schools is that possibilities to devote oneself to problems in a peaceful and trusting atmosphere are offered. (Johnson, S.M. 2004, 17)

Teachers need to interact with teachers from their own and other schools and with the surroundings. Only thus can they notice meaningful signals that might help them to predict occurrences and changes, which make it possible for them to develop their own work accordingly (Juholin 1999, 41). Direct ways of interaction are face-to-face meetings and individual contacts, days of open doors, and larger events and celebrations. However, the individual or small group contacts that would be most profitable are very sparse. They are often not welcomed, even rejected by the receivers of the communication invitation. The right means for such inter-group communication have not yet been found.

3.5 How to define the team concept

The team concept is used in many different connections like when talking about sports, teamwork, working groups, management groupings, and two-person pairings. There are almost as many different definitions of teams as there are individuals trying to define them. The western human being exists in a world where individualistic performance and qualities are highly appreciated; only in order to gain something or to fulfill some needs individuals join forces. Together they have more skills and greater knowledge than any one alone.

3.5.1 Purpose and performance

Generally one can say that a team comes into being as a result of some challenge. Adaptability to new circumstances is demanded of everyone living in today's society. Especially work undergoes changes and this has implications for the behavior of employees. A change always is a challenge. Although individual talents are highly regarded in our society, human beings are social creatures and in critical situations have learned to find help from each other. In trying to answer a common challenge they then are able to react more quickly to changing situations. When overcoming hindrances together they start to trust and believe in the abilities of the other. And they find that it is enjoyable to work together. They are on the way to becoming a team. (Katzenbach and Smith 1993, 18)

A team does not come into being if there is no challenge that would appeal to all the members of the group. A good understanding and a wish to form a team can promote the values of the group's work, but to do teamwork is not the same as to be a team. Common, demanding performance targets that are seen as important to achieve usually bring about both performance and a team. Performance is essential for a team. If the potential team does not succeed in becoming a real team, the performance will be worse than in a work group. Time is lost on useless communication and interaction.

A challenge will always be connected to a vision of how things could be. Once the group has arrived at a clear sense of its own purpose it can begin

to lay out goals. Specific performance goals are always directly connected to the purpose of the performance and this purpose usually is formed in accordance with the challenge. The group now has reached the first step of becoming a team; it has the potential possibilities to perform. Real teams do not end the discussion of values and visions during their whole existence. In this way the reason for their performance is continuously clarified. The purpose of the performance gives an identity to the team. Thanks to this identity conflicts in the team stay constructive. Each member knows when individual aspects are about to disturb the coherence and when the interests of the team must have priority. Detailed performance goals that are achievable help to form the identity. Communication and interaction is advanced. An action plan or strategy is developed. Looking for the best ways of collaboration the members are encouraged to try to overcome hindrances in their way. Results of the team's work, where every member has made his contribution, are valuable for the mutual accountability in the team. Trust and commitment to each other are the foundation for this accountability, which in principle is nothing but a promise to take on the responsibility for fulfilling the purpose of the team. (Hoover 2002, 55-64)

The concept of leadership can be understood as a process, in which an intentional influence on an individual is exercised by another individual. The leader supports and facilitates the team member's learning and problem solving processes (Hoover 2002, 19). Leaders are all-round heads of teams, responsible for conducting a group of employees with many different competencies. They influence the composition of the team and the support, which the team can get from the outside. They also may have an emotional influence directed at and adjusted to the individual member. This, however, includes risks for manipulative actions. (Argyris 1992, 311) The leaders also influence the team's creativity and innovative skills. However, the leader of a team can be said to work against her own survival as leader, because her aim is to diminish the need of her contributions as much as possible. (Argyris 1992, 147-148)

When a team is formed in an organization the manager usually takes on the responsibility of deciding the tasks and dividing them between suitable individuals, which then are supposed to form a team. (Juholin 1999, 63;

Belbin 1993, 40) The manager can also appoint one team member in turn and thereby allow the already appointed ones to influence the next appointments. Know-how, experience and potentiality for development are important criteria for membership in a team. The potential team should be allowed to form it's own visions and values. The purpose of its work should be discussed and settled again and again between the members. The target for the work and partial goals together with the strategies to achieve these need to be posed by the team members in order to increase their commitment to the task. Purposive team members might exclude uncommitted individuals from the real team. This is an easy way to change the membership of a team and to maximize efficiency and performance. A well-balanced team is self-contained. (Belbin 1993, 84)

The members of a potential team join forces of their own free will in order to cope with a problem. They are all challenged by the task in front of them. In discussing the purpose of their work each of them silently takes into account what abilities and skills as well as weaknesses they have, separately and together as a team. In this way their aim is modeled according to their abilities. Each member takes on her part of the tasks. Requested abilities for a good team performance are technical or functional skills, problem-solving and decision-making skills, and interaction skills. (Katzenbach and Smith 1993, 47) Skills, which the members see as necessary but missing, can either be learned by one or more members (Belbin 1993, 78), or the team can invite an additional person having these requested skills to join them. Concentration on the performance is essential for a team, not so much the similarity and agreement between individuals. This will grow from itself during the development of the team. Interpersonal chemistry (Belbin 1993, 56) must not influence a member's sense of the other's skills and knowledge. What is good for the team is also good for the team member.

3.5.2 From work groups to top performance teams

In a work group each individual takes responsibility for her own work. Those who plan and decide what the group or the individual should do are usually different from those who work. The total performance

is equal to the sum of the performances of the individuals. Functional efficiency can be increased only by more efficient individual performance of the own limited tasks. Work is controlled from the outside. The day's work time is fixed and so is the salary. (Katzenbach and Smith 1993, 211) In most situations the individual accountability and the performance model of the work group fulfill the experienced needs. In the best work groups the members share information, points of view and ideas. They make decisions that support improvement of work strategies and performance norms. In the case of big changes and challenges, however, the interdependence of the members would need to increase more than what usually is assumed to be possible in a work group.

In organizations team-like groupings of a permanent structure, specified as different work groups, performance and production teams, can be found at any level. These teams belong to the infrastructure of the organization and should be separated from teams that operate solely on team principles, established for certain projects. Organizations usually define teams as "… a group of people who is organized in a permanent nature … and handling a certain whole of an organization's operations." (Pirnes 1996, 101) Primary motives for creating such team structures are according to Pirnes better customer service and creation of a direct connection between customers and team. The members in the team have "to understand their personal responsibilities as well as their responsibilities towards the community." (Pirnes 1996, 102-103)

Real teams can develop out of potential teams only through risk taking concerning trust, interdependence and hard work. In order to move from individual accountability to mutual accountability the members must trust each other, not completely and not forever, but in questions concerning the team's ultimate purpose, performance goals and process strategy. Such trust and interdependence is hard to achieve, it has to be earned and it has to be shown again and again, if it is expected to influence the behavior of the members. (Hoover 2002, 157)

There are many existing team development models; one model for developing high performance teams is presented by Wilemon and Thamhain (1983). It contains most of the features of a real team. The first

developmental step is recruiting of team members. The prospective team members would be asked to sign up for the project, thereby promising to do whatever is necessary for success. The effective project leader will try to clarify the motivation of each team member as early in the project as possible. Secondly the climate for team development will be set. The need for high performance and, therefore, for team development is discussed. The project manager informs individual team members about professional growth opportunities. Team members should be given some power and influence over the project's direction and management. In phase three the goals should be agreed upon, clarified and linked to team members. Role clarification constitutes the fourth step. Here individual responsibilities and how they affect other members' or the group's responsibilities should be discussed. The fifth step is the development of operating procedures. When the team has agreed on mission and goals, performance roles and procedures, the sixth step concerns decision-making. Here a problem solving method is suggested. There should, furthermore, be adequate controls in order to keep the team on track. This seventh phase can take place as follow-up discussions at review meetings. (Wilemon and Thamhain 1983)

The members of a top performance team work very closely together. Not only are they all committed to the common goals and purpose of the team, they also develop commitment to each other. They develop a deep self-insight, when they realize how others perceive them (Belbin 1993, 43, 77). They care about and support the other as well as attend to the vision they try to accomplish. This enables them to develop interchangeable skills and flexibility. (Katzenbach and Smith 1993, 37, 66) In top performance teams the role of the leader can be possessed by any team member and be changed according to tasks. (Katzenbach and Smith 1993, 39) Performance results and consensus are more important than anything else. The member sacrifices individual free time and off duty interests, she works day and night not even expecting any kind of acknowledgement other than success in the performance. The family is forgotten, there is a new family, the team, that means everything. It is clear that such a team can exist only for a period of time. When the task is performed, the team breaks up. Maybe new members are included or old ones leave. A new task may need other sorts of skills. The

new potential team has to start building its performance strategies and discussing vision and mission almost from the beginning.

3.6 Teams as communicative systems

When a team is formed, the new team members have to get acquainted with each other. In case the team is very heterogeneous the process of learning to know each other can be both difficult and painful for the team members. In the beginning the task or goal of the team performance is most important. The conversation revolves around different ways to tackle the problem. In this way team members are enabled to "indwell" (Nonaka and Takeuchi 1995, 56-71) into others and to grasp their world from inside.

Sometimes the struggle to understand each other leads to deep conflicts; especially, if one is sure that one's own perspective is the only right one. A key way to build mutual trust is to share one's original experience. But it is often difficult to listen to the other and try to understand her very different opinions. The members of the prospective team might not be able to agree on anything else than that they do not agree. This might mean the end of common attempts. But from this chaos a first spark of grasping can flare, if one is ready to listen to the other (Hoover 2002, 31; Juholin 1999, 58). It might be worthwhile to take the risk of conflicts, because the bigger the heterogeneity of a team is, the broader its competence is, and the performance can reach its maximum.

3.6.1 Team learning

A complicated chaotic system can become self-organizing (Argyris 1992, 68; Juholin 1999, 38). Integrating different people into a team means merging visions, values, capabilities and cultures. The common goal and contextual features of communication are indispensable if a self-organizing process is to take place. A new strategy can develop out of uneasiness and unbalance. Different fragments are joined to wholes in communication. Then it is possible to understand a problem in a new and deeper sense. The continued dialogue between explicit and tacit

knowledge drives the creation of new ideas and concepts. (Juholin 1999, 38, 39)

The dialogue between the members of a team creates understanding. Different opinions are honored. Questioning and listening are founded on equality between members. The team performance is supported. The individual development is also promoted. The members take responsibility for the performance of the team and the interaction inside the team.

Teams have a central role in the knowledge creation process. They supply a shared context for interaction in which new points of view are created through dialogue. Thereby tacit knowledge becomes explicit; explicit knowledge is linked together; internalization takes place. (Nonaka and Takeuchi 1995, 56-71) The communication between team members and between teams has been considered as a means of developing the learning process of the organization. Knowledge is not just information or facts. It is also a dynamic human process of justifying personal belief.

A socio-cultural approach to human learning and development sees thinking as something one takes part in and cognition as developing between individuals that are involved in common activities. Learning is founded on social experience and everyday conceptions. Each time knowledge is applied or practical tools are used this happens in new situations. Thus there is always a possibility that new and creative elements appear. These might change the nature of knowledge or the use and application of tools. (Minick, Stone and Forman 1993, 11)

Human agency can be defined as the carrying out of mental processes. It is the capacity to make choices and to impose these choices. Agency can be assumed to apply not only to individuals, but also to groups functioning on the intermental plane. Vygotsky (Wertsch et al. 1993, 342) was concerned with signs as mediators of human action. Such mediational means as language, algebraic symbol systems and works of art are products of socio-cultural evolution and are appropriated by groups or individuals as they carry out mental functioning. These can be pictured as mediational agencies.

The human activity requires interpretation. A social negotiation of meaning takes place in practical activity. Through interaction collective knowledge is produced. This includes negotiated meanings and understandings, common sense and social norms. Also socioemotional components are involved. The learner internalizes this knowledge and revises her own understanding (Hatano 1993, 164). As the learner continues to learn she builds on these prior understandings for further interpretation. She now uses her new insights and the present point of view, and increases her understanding as she proceeds. This hermeneutical spiral describes the process of growth and change taking place in the learner. It differs from the hermeneutical circle in that it includes a time perspective.

Together the members of a team reflect on the actions undertaken and the results achieved. They give each other feedback on the performed work and suggest improvements for the next steps. In a team, where the members trust each other, and where the goals of the team are more important than the individual goals, such moments of dialogue can be very valuable. Positive feedback is a control of how one appears to others and increases the self-esteem. Self-knowledge is a motivator for growth and improvement. Negative feedback seldom comes from inside the team, but can be given from outside, especially by chiefs and other persons sitting higher up in the hierarchical tower. Such feedback can be devastating for the motivation of the team. Positive feedback from outside the team, especially in form of rewards, can also have a bad influence on the performance of the team, because the team members can loose sight of their common goal and start producing in order to get rewards.

When team members strive primarily for unanimity and only secondarily for allowing alternative perspectives, groupthink arises. It is assumed that the team has agreed on the action to be taken if no disagreement exists. Pressure is used to silence alternative opinions. Hesitating members do not speak up. Information is pushed aside as not relevant. As everyone knows the task the course of action must be correct. The team works effectively and harmoniously; it cannot be in error. In this way a catastrophe might develop. (Hoover 2002, 60)

3.6.2 Competence of a team

The competence of a team can be described as task centered and interaction related. The communication inside the team is good, if the team reaches its goal in such a way that no one is harmed, the members are pleased with the discussion, and the feeling of belonging together is increased. Task centered competencies (Hoover 2002, 83-86) are, for example, skills to express one's thoughts and feelings in a precise and adequate way, skills to listen and understand what the other says or by other means expresses, skills to use the contents of another speaker's talk in one's own contribution to proceed with the discussion, skills to upkeep the coherence of the discussion, skills to ask for more details and explanations, skills to define and analyze problems, and skills to present, develop and assess possible solutions. Relational competencies (Hoover 2002, 89-90, 95) are skills to adjust oneself to situations, subjects and others, skills to show empathy and give support, skills to control conflicts and solve misunderstandings, skills to pronounce one's own activity and readiness as well as skills to activate and encourage others to take part in the activities of the team. Key achievements of a good internal communication are open interaction and expression of opinions. Commitment to an approach and motivation to perform arise out of such discourse. It is important to be able to listen to others (Hoover 2002, 31), to draw conclusions of what one heard and, when necessary, to ask questions (Wyss-Flamm 2002, 156). It is good to be critical and to be able to assess. One should ask for specifications and find support for opinions expressed in the team. Just as important is to express acceptance, devotedness and engagement in the team activities. This often implies energetic and purposeful nonverbal communication. A change and growth in understanding and performance can be the result. (Hoover 2002, 8-33, 190)

In a team performing at the top it is significant that the members have developed a deep friendship. They spend much of their free time together. They know each other through and through. Sometimes a look or a gesture is all that is needed to understand each other. Affection and devotion, the wish to help a member of the team to achieve as good a result as possible, even at the expense of one's own personal interests,

these are features shown by the members in a top performing team. The joint enterprise and the friendly atmosphere create a context, where informal and trustful communication takes place (Hoover 2002, 31). An honest exchange of opinions and free ideation invites to creativity and innovation.

3.7 Creating shared meaning

The actions of human beings are determined by needs (Hoover 2002, 11). A person needs to feel that she belongs somewhere, that she is loved and that she is able to influence her own actions and have an impact on others. Nowadays staff and collaborators form increasingly heterogeneous groups and because of the globalization of the organizations more and more of the stakeholder groups represent different cultures, ideologies, and values. Communication must take this into account. It has to be tolerant and flexible. New specialist employees with other opinions about commitment and organizations must also be accepted. Perhaps new common cultures and values have to be created. (Juholin 2003, 73)

When a team is formed of people with very strong and very different individual needs, conflicts can be expected. There might for example be a difference between cognitive styles. If one person has a logical style and the other an affective style, this can become an obstacle to teamwork. Further on, a dominating style that comes to be perceived as the right one will destroy counteractive influence. The weaker personality fears to speak, feels unwilling to participate or conforms to all suggestions. (Hoover 2002, 137)

Individual goal accomplishment is limited in teamwork. Communication between team members can lead to the creation of conflicts. These can be rooted in the substance of the task or in interpersonal relations. There is no reason to avoid conflicts. On the contrary, if a team is able to survive chaos and conflicts, it has the chance to develop into a high performing team, where the performance is bigger than the sum of the performance of individual members.

With the concept "social competence" we understand many abilities connected to tacit and explicit communication, understanding of self and others, problem and conflict solving and teamwork. In everyday circumstances the concept describes the skill to communicate and interact with others in a meaningful way. This skill is dependent on the context. It can change from community to community and depends on historical time. (Vlasits 2005)

When society demands that schools should teach their students social competence to a higher degree than previously, this must not be a question only about training of social strategies needed at the time being, but a competence to act in a communicative way founded on the basic principles of self-determination, democracy and human dignity. (Vlasits 2005)

Social competence can primarily be understood as an ability to engage in dialogue, where not only things are considered, but also the mind as an authentic relation and the intellect in search of common sense. It is the foundation but also the fulfillment of all ethic requests, the ability of "I" to join the "you" in a dialogic interaction. (Vlasits 2005; see also Palmer 1969, 193; Gadamer 1975, 352)

In this context dialogue is not defined as a skill, but as a fundamental recognition of the truth of "I" and "you", which is no hidden secret but should be something selfevident. However, that this is not always the case we recognize from many unsuccessful talks. Conflicts of interests or unbridgeable ideological differences are given as reasons for interrupted talks. The counteragents were not able to overlook their own factual interests in favor of recognition of the "you". Then the counteragents have forgotten that the human being as subject does not form a whole or a real unity. Only in relation to "you" this holistic entity is constituted. (Vlasits 2005)

A real dialogue is a symmetric relationship that demands respect and acceptance of the "you" with all its differences, also when our minds revolt. Dialogue does not mean to avoid conflicts. It means to say "yes" to the other, who in her whole being is different from me. It does not mean to say "yes" to her ideas. When the counteragents are truly open

to each other, there is always a possibility to come to agreement without having to give up the differences. (Vlasits 2005)

Bohm suggests a generative dialogue between heterogeneous groups as the foundation of a renewal of our culture (Bohm 1998, 33). Groups that are involved in generative dialogue meet regularly for discussions and conversation. This gives the opportunity to examine one's own apprehensions, to observe one's own way of thinking and feeling, and to generate new aspects. It also means that the processes of thinking and communication are allowed to take their time. Such indwelling (Nonaka and Takeuchi 1995, 60) creates new images or patterns and breaks dichotomies between mind and body, reason and emotion, subject and object, knower and known. Anything can be the theme of such a discussion; there is no defined aim and no pressure for results. But perhaps a common meaning can be found behind all the differences and a new understanding can develop.

A generative dialogue is an exercise in openness. This means to take part, not as knower, but as learner. It is necessary to question one's own positions and, perhaps, to suspend them. One should realize that one has only a part of the truth, the other has another part. There is no reason why my truth has to be implemented. A linear discourse is thus not possible, but new aspects might develop. And the contact to the other is reestablished.

The free conversation has not been seen as a primary form of communication. It is, however, similar to Gadamer's description of the fusion of horizons (1975, 370), where what people create collectively is something that no one of them could have created alone.

In the school community interaction between teachers and students are the foundation of the instructional process. Interaction between peers is seen as important for development of social competencies. Communication both inside the school and with the social environment is significant for the knowledge society. In each school there is nowadays a work group that concerns itself with school internal conflict situations. Diffusion of knowledge between teachers, but also between students and teachers and between parents and teachers, is a recurrent problem in

school. The working in groups or teams becomes more and more popular among teachers as well as students. In my study I must deal with all these features. In the next chapter I will describe the action research methods I use. In action research two parallel sets of learning take place: learning about the practices under study and learning about the processes of studying them.

4 Methodology in a narrative research approach

The first known attempt to establish a science of teaching was made in 1657, when Comenius published his Didactica Magna. He suggested dialogue as a method of teaching. Already 400 years ago he realized that there are many ways of solving problems and many perspectives from which phenomena could be understood. Students are asked to look for and find out explanations to encountered phenomena. (Comenius 1657, chapter 12, §44)

In the following centuries general teaching methods have been rather scarcely investigated. One reason might be that in student teacher education teaching methods are connected to practicing in class. Practical experience has been seen as more important than theoretical knowledge. During the last few decades this attitude has, however, changed and research in this field has developed (see e.g. Keinonen 2005, 183).

A didactic theory for instruction could be grounded in the teachers' intentions and strategies of teaching. Already John Dewey (1916) was of the opinion that the relationship between experience and learning is central in the methods of teaching. Experience is a concept that exhibits interpretations of facts encountered in life. The task of science is to organize experiences to conceptions in such a way that practice is enlightened as a thematized and interpreted concrete whole (Marton 1987, 34). In international research (Neave and Jenkinson 1983; Keating 1974; Gage 1963; Kitchener 1993; anon. e 2006; Holmqvist 2006; Flick and Lederman 2004) on teaching three principles can be distinguished. The first one draws conclusions about teaching methodology not caring about the contents or contexts of teaching. For example results of learning in teamwork and in listening to lectures are compared. As a result the question of how the student organizes her learning in the best way arises. This is considered to be independent of the contents of the teaching. Another example could be a comparison of the degree of doing homework between students from different social categories performed neglecting the different conditions under which the homework takes place (see also Malin 2005, 103). The second principle assumes that the results of teaching can be measured as repeatable memorized knowledge. The third principle is founded on the assumption that teaching has to be

connected to the way in which the student understands the contents of the lesson. Teaching and learning are connected to each other through their contents. That the content and the process are two different but interdependent parts of the learning event can form the scientific ground for a methodology of teaching. In this way the teacher's experience as a theoretical concept becomes a part of the theory of teaching methodology (Ruoho 2004).

In this study methods of teaching and learning are investigated in a problem solving environment. The process of gathering data and writing a text that explains data takes the form of a narrative enterprise. To me this approach is the most useful way to develop my own understanding of the change process that takes place. Narrativity cannot be considered a research method, but is an incoherent set of inquiries that have connections to narratives. It thus refers to a large number and a great variety of approaches (Hänninen 2000, 16). These range from those in which the conception of a narrative is that of an account over those in which discourse is understood as narrating to those in which discourse is narratively analyzed. The different meanings of the concept narrativity refer to the process of narrative knowledge, the nature of the research data, the ways of analyzing data, and, eventually, to the practical meanings of the narratives. At the core of any narrative research process is analysis of narrations or stories[11]. Such analysis produces a new story from the narratives in the data. This story, interpretive from original texts, is in itself fictional. (See e.g. Keinonen 2005, 60; Kohonen 2007, 67-91) In my study I produce a narrative by interpreting the narratives in the data (TABLE 1, Figure 2).

TABLE 1. Views of narrativity in this study

	Narrativity as phenomenon	Narrativity as method
PLOT member	Narrative identity	Interviews
Action research	Narrative knowledge	The results of this study in the form of a narrative

11 The two concepts are here used synonymously.

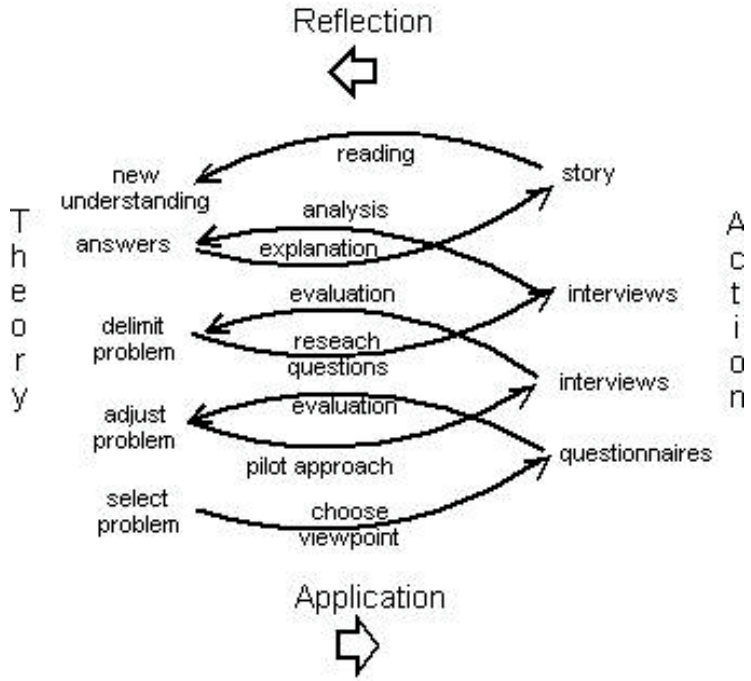
Stories have to do with how participants interpret things, what things mean to them (Bruner 1990, 51). Between life and stories a hermeneutical spiral develops. The human being interprets her life using symbols, texts, and stories. Human action and experience in time form the prior understanding of life. The narrative configures life, forms the plot or meaningful wholeness. And, when the narrative is used as a means to understand the listeners' own life, it refigures life.

The narrative perspective on research is closely connected to action research. Both should be of benefit to the subjects of the research. A central message of action research is that it should not only describe the world but also change it to the better (Syrjälä and Heikkinen 2002, 158). Narrative can be considered as a mode of knowing (Czarniawska 2004, 6). People construct their knowledge and identity through stories that describe a sequence of actions and experiences of some characters. These characters are exposed to changes in their situations. Hidden aspects of the situations and characters are revealed. New predicaments call for thought and further action (Ricoeur 1981).

The philosophy of narration has its origin in the tradition where conditions of human existence and experience (Heidegger 1927), human temporality (Heidegger 1927), and interpretation and understanding of human action (Ricoeur 1981) is considered. By joining a community individuals can connect their own particular stories to a larger whole. Families, religious groups, political associations, teams in organizations, and unions offer such frames for collective stories. Narratives act as compasses, enabling communities to assess where they are and where they are headed. - In this study I tell the story of a team (Figure 2).

Also the researcher's narrative presents an interpretive theme. The reader enters into the story and undergoes a holistic emotional experience. The life likeness or verisimilitude of this experience supplies the reader with a mode of knowledge. In my narrative the theory of organization psychology forms the perspective. The methods I use to analyze data are hermeneutical interpretation and phenomenography.

Figure 2. Hermeneutical spiral that describes one of the most important knowlwdge creation processes in this study



4.1 The research questions

For the innovative learning process to occur in the classroom the choice of didactic method is of utmost importance. The process of problem based learning has effects on both horizontal and vertical grade instructional articulation. As teachers of the same level work together to prepare the learning units, they have the opportunity to communicate with each other and share their instructional objectives and come to an agreement based on the national curriculum. Furthermore, as teachers of different levels practice and recognize what is expected in the learning units crafted by subject teachers, they also gain an awareness of their role in terms of the students' education.

There are numerous definitions and interpretations of problem based learning (PBL). Originally PBL was seen both as a curriculum and a learning process (Barrows 1985, 3, 45, 53). The curriculum consisted of problems that demanded acquisition of knowledge, problem solving skills, self-directed learning and team participation skills. The process replicated the systemic approach to resolving problems or meeting challenges (Barrows 1985, 20, 53-85). A key point for the teacher is to find that definition of PBL that best fits one's own teaching philosophy. Boud & Feletti (1991), for example, suggest confronting students with practical problems, which stimulate and motivate learning. Other modifications occur if one wants to apply the method in science education. Then students may be asked to supply a hypothesis, suggest a way to test the hypothesis and perform experiments. Students discover the need of specific knowledge. This knowledge can be supplied in the form of lectures given by an expert. In my study I have used this modification (Dumbrajs 2000; 2001) According to Barrows (1985, 3, 76, 102) problem based learning, regardless of subject matter, can enhance students' achievements of adaptation and participation in change, application and problem solving in new situations, creative and critical thought, adoption of holistic approaches, appreciation of diverse viewpoints, promotion of self-directed learning, and good communication and leadership skills.

Problem based learning in small groups assumes that the collective resources of the group will be used to enhance the learning of all its members. Successful group learning depends on a high level of group functioning. The group needs to develop to a real team, going trough the processes described in chapter 3. Individual conflicts must be resolved, trust between members established. Win-win solutions are desired. They help the team to continue deepening trust and learning. Members are willing to change their preconceived ideas or opinions on the basis of facts presented by other members. Leadership is shared. (Walsh 2005) Teachers have the task to facilitate the learning process, a role that differs considerably from traditional teaching. The introduction of PBL involves major changes in the process of teaching and learning. Both teaching staff and students have to learn to operate in a different manner. In PBL environments students act as professionals and confront problems as they occur - with fuzzy edges, insufficient information, and a need

to determine the best solution possible by a given date. (Stepien and Gallagher 1993)

In the following I consider school as an interactive and communicative system. Conflict situations appear and diffusion of knowledge is slow and problematic. As a means to overcome such difficulties and to cope with change situations, the work of teams and sharing of knowledge can be utilized. My interest is directed at teachers' experience of teamwork and the reflective dialogue as a means of learning. As teachers change, they induce a change in their classrooms, too. And, when they react to change, they influence their colleagues and their community. My own position is that of a subject teacher and I was a member of the teacher team under investigation.

The present turbulent situation in comprehensive schools with rapid changes both in instructive methods and contents is challenging for both teachers and students. Therefore it is of interest to find out how teachers cope with the new demands and how students answer to and accept new learning processes. I can now delimit and elucidate my research problem by directing the following questions to myself:

A. How do teachers experience their own learning when they together try to improve the learning process of their students?
   a. How do they define the team concept?
   b. How do they describe their experience of working in a team?
   c. How do they perceive the possibility of dialogue?

B. How do students experience learning in problem solving situations as compared to learning by transmitting methods?
   a. How does the use of prior knowledge influence their experience of learning?
   b. What kind of learning do they approach?
   c. In PBL situations, how does their social competence develop?

C. Which are the problems that primary school teachers experience as most demanding, when they start to teach physics and chemistry?
   a. How do they respond to the subject knowledge request?
   b. Which pedagogical methods do they prefer and why?
   c. How does knowledge diffuse in and between schools and instances?

In this study I have tried to find an answer to the above research questions.

The approach of investigation that I have applied is action research. In the investigation I have made use of phenomenographic methods in the analysis of interview material. Hermeneutic methods were applied in an overall sense when I tried to understand the experiences my informants described.

4.2 Action research

Action research is often performed by a group of teachers, perhaps working alongside a researcher. Action research always includes an intervention in the real world and an examination of the effects of this intervention. Through the results it might be possible to influence other teachers to use and value a more applicable teaching method. Action research is a cyclic process. Each cycle contains self-regulation, collaborative action and communication. An overall definition of action research is given by Kemmis and McTaggart (1988, 5): "Action research is a form of collective self-reflective inquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices, as well as their understanding of these practices and the situations in which these practices are carried out … The approach is only action research when it is collaborative, though it is important to realize that the action research of the group is achieved through the critically examined action of individual group members." The research methods are chosen so that they can describe the research problem in question. Often deep-going interviews or partaking observations are used.

Action research requires theory in the sense of speculation on the hypothetical meanings of the immediately observable. This involves questioning the meaning of data and is essential to the reflective process that brings alternatives into view. It is part of the collaborative, negotiating process and thus also part of the search for change. Action research involves above all the integration of a variety of theoretical

perspectives. It is about deciding on courses of action. An effective relationship between different theoretical perspectives generates its own form of theory. (Winter 1997)

Action research shifts its focus as the inquiry develops. Therefore previous relevant knowledge cannot be initially reviewed. The theoretical basis for the work cannot be determined in advance. Action research must aim at being flexible and creative as it improvises the relevance of different types of theory at different stages. This dimension of action research may be considered as a journey of self-discovery. The process of inquiry draws on a whole variety of different types of theory: theories of language, of learning, of group dynamics, of motivation, of ethics, of organizational structures and of change processes, among others. The series of negotiations through which we involve participants, establish and develop the focus of the work and interpret events contribute strongly to what we learn from the inquiry. (Winter 1997)

4.2.1 Hermeneutics applied to action research

Interpretation of actions requires a mediating step such as is provided by for example field data, audio or video recordings. By the use of such mediating devices actions are preserved in order to be more closely studied at a future date. Hermeneutic methodology[12] is applied in the interest of formulation of an understanding. This hermeneutic process can also be described as a sense making process, as when teachers share their experience between each other. The methodology of understanding in the cultural sciences was modeled on the interpretation of a text and became the expanded notion of hermeneutics.

The word hermeneutics can be derived from the name of the Greek god Hermes, the messenger. He acted as an intermediary bringing messages from the gods to the people. The way in which the messenger delivered the message could have either of three distinguishable features. He could

12 According to Wikipedia (anon f), The Free Encyclopedia, a hermeneutic is defined as a specific system or method for interpretation, or a specific theory of interpretation. However, Gadamer (1975) has said that hermeneutics itself is an approach rather than a method. With Gadamer "the older conception of hermeneutics as the methodological basis … is left behind" as noted in Palmer (1969, 163).

pronounce his message, he could explain the contents of the message or he could translate the message. These three features define the three methods of hermeneutics even today. (Palmer 1969, 13)

To pronounce is really already interpretation. We can just think of how an artist interprets a song or an actor a role. Literature also becomes more vivid through the impressions that pronounced words make. For ages the great works of literature were intended to be declamed and listened to. Written texts miss the originality of pronounced words. (Palmer 1969, 16) Today an alienation from the strength of the living word takes place. But real talk in everyday life between people who understand each other permits the pronounced and unpronounced to follow each other as a whole. This allows the listener to understand also that which cannot be said with words. In conversation it is thus possible to externalize tacit knowledge. (Nonaka and Takeuchi 1995, 13)

The secretive messages of the Delphi oracle were pronunciations, but at the same time they expressed and explained something formerly unknown. They expressed the importance of some circumstance and explained something about the situation and about reality with words. Something was made clear. In this way an utterance could tell about truth and falsehood. (Palmer 1969, 23) But how is it possible to understand a formulated pronunciation? Something is formulated and expressed and that what is intended to be understood is also understood. The listener hears a series of words and through some mysterious process she intuitively understands their meaning. This mystic process is the hermeneutic process. (Gadamer 1975, 156) Hermeneutics is the skill to listen (Heidegger 1927, 163; 1959, 122; Gadamer 1975, 457; Schleiermacher in Palmer 1969, 86). There is a relationship of dialogue between the interpreter and a text to be interpreted (Ricoeur 1976, 16). Not only the interpreter questions the text, but also in a deeper sense the text poses questions to its interpreter. To understand an old text is sometimes difficult because of the foreign context. For the modern human being it is difficult to imagine how it was to live for example in ancient Greece. (Gadamer 1975, 157-161) But also modern texts often contain encounters with foreign contexts. The two worlds, the world of the text and the world of the reader, are present. When we understand

and are able to reveal the secrets of the text, then the horizons of the two worlds have merged (Gadamer 1975, 305).

When translating a text the origin and context in which the text was created must be taken into account. It is not enough to make a grammatically correct translation. The text has to be understandable to the reader. Is it then correct to translate also the context to the reader's corresponding circumstances? When one attempts to separate the true message of the text from its original context, one must take into account that the underlying sense of reality and the way of being-in-the-world which the original text mediates are fundamental to the interpretation of the text. (Gadamer 1975, 157-163)

Interpretation

Hermeneutics has been defined in several ways over time (e.g. Palmer 1969, 33). Each perspective illuminates different sides of the problem of interpretation. The theory of interpretation nowadays concerns less the right interpretation and to a higher degree the ontological question, the question of being. Schleiermacher (according to Palmer 1969, 87-90) distinguishes the interpretation of language from the interpretation of thought. When interpreting thought subjective and individual features are heeded. Therefore a feeling of kinship, to at least some degree, towards the speaker is demanded. As an end result the listener will understand the speaker better than she understands herself. This is possible, because the listener sees the context in which the speaker pronounces her message. In arts it is known that different critics find different meanings in the same work of art. Because of this to understand a work of art better than the artist is not necessarily due to the subconscious expressions of the artist but can be derived from the world of thoughts of the interpreter. Thus "better understanding" would not imply "to know better" but further development of the work. (Ricoeur 1976, 23)

When hermeneutics is defined as an investigation of the understanding of the deeds and the performance of human beings, the interpretation as meaning of language is transcended. We move from a hermeneutics that with the help of rules and methods tries to understand the true

meaning of texts, to a hermeneutics that investigates how the human being understands herself and her world in a historic context. What is the being of the being, who understands herself and her world? (Heidegger 1927, 8) According to the ontological hermeneutics human beings are beings that form themselves. The human being is what she makes of herself. Because we are in connection with things and phenomena in our everyday lives, we already have a conception or pre-understanding of their importance and meaning. This tacit knowledge (Nonaka and Takeuchi 1995, 13, 59) that appears in language and action is more original than the expressed, explaining knowledge.

During the interpretation meanings which are hidden parts of the totality of meaning that carry the interpretation forwards are revealed. The object of interpretation has to be highlighted so that it can be interpreted according to the perspective given by this totality. Highlighting it supplies it with a forecast meaning, which depends on the intention of the interpretation. This looking ahead that conducts the interpretation Heidegger names fore-sight. (Heidegger 1927, 148-153)

If the interpretation is linguistic, the sphere of concepts can be derived from what should be interpreted, or an enforced, unsuitable category can be used. The selection of a sphere of concepts thus is a solution on the ontological level. The hermeneutics depends on the fore-conception and the choice of categories. (Ricoeur 1976, 77-78)

The fore-sight and the fore-conceptions form the theme of the interpretation. They in a concrete way predict the meaning. Both are grounded in the totality of meaning of the fore-having. All three together form the fore-structure of the understanding or the prejudice of the interpreter. According to Heidegger (1927, 152-153) all interpretation that should lead to understanding has already understood what is to be interpreted. To his opinion the circle is no problem. Decisive is not to get out of the circle but to get into it in a proper way. The hope to be able to interpret without fore-conceptions and prejudices vanishes when we examine how understanding takes place. The impression one becomes from an object is depending on one's awareness of the object. The subject matter of the world brings into light that which is perceived

in the understanding of man. The object as such is not self-evident. The definition of self-evidence leans on unnoticed prejudices that are present in each interpretation. (Bleicher 1980, 120 – 126)

Interpretation leads to a mediate knowledge about existence. It does not only aim at the meaning of the text. The text is interpreted with the intention to understand the existence that is disclosed in the text. Hence interpretation is both purposeful and existential. Hermeneutics listens to the pronouncements. Prejudices may be distorted. But the best possible reflective use of prejudices may lead to an authentic interpretation (Gadamer 1975, 270). Interpretations are not, according to Gadamer (in Palmer 1969, 215), true or false, but authentic or unauthentic in relation to how well we have succeeded to unfold our own prejudices, from the ground of which understanding occurs, when the interpretation horizon coalesces (Gadamer 1975, 305). - Hermeneutic reflection makes "becoming aware" possible (see also Marton and Booth 1997, 143). It might display what otherwise would occur behind your back. But it cannot lead to a complete freedom from history and tradition.

We understand something by comparing with what is already known and mastered. That which we understand forms a systematic cyclic whole, which is built up from smaller parts. The whole defines the individual parts and the parts together form a circle. A complete sentence can be seen as such a whole. We understand what a single word in the sentence means from its connection to the whole sentence. The other way around we understand the sentence from the meanings of the single words. A concept gets it's meaning from the context or from the whole to which it belongs. But the whole is formed precisely out of those concepts, which give it meaning. To understand is a cyclic process. The cycle is hermeneutic. Meaning and meaningfulness originate from parts of the hermeneutic totality and its wholeness. But the development of the concept of meaning itself depends on the context. In different contexts the totality might get quite different meanings. With time an expression might change its meaning. Meaning is thus a historic concept. We understand a meaning from the perspective that is formed by the time in which we are living. The hermeneutic circle has a historic dimension. (Heidegger 1927, 153; Gadamer 1975, 268)

The hermeneutic circle is not logically usable. If we have to understand the whole before we can understand the parts and, the other way around, if we have to understand the parts before we can understand the total, we will never understand anything at all. Schleiermacher (in Palmer 1869, 87-91) distinguished two parts in understanding, comparing to known things and intuitively knowing. It is necessary to intuitively jump into the hermeneutic circle.

A condition for a dialogic relation is a tentative sharing of meaning. In addition to the language the speaker and the listener have to share an acquaintance with the object to be discussed. The shared understanding of the speaker and the listener can be considered to form a hermeneutical circle. This means that the information that is looked for with the help of communication already is known. But this is how it is. To be able to discuss something one has to know something about the subject. The listener starts from the pre-knowledge, which she shares with the speaker. Intuitively she moves inside the co-central spheres all the time using the already known in comparing it to new knowledge. (Palmer 1969, 96)

The interpretations of language and thought together form a totality. The interpretation of language shows the connection of the utterance to the formation and interaction of sentences and also the linguistic differences and similarities in utterances. Thereby there is movement from the parts to the whole, or the other way around, so that the interpretation of language takes place in the hermeneutic circle. In Schleiermacher's thinking the text, the utterance, was always the starting point (see Palmer 1969, 88). He tried to find the laws, with the help of which it would be possible to understand the text and the author. For him hermeneutics was a way to understand the speaker from the origin of what this said. The language was in a key position. (Gadamer 1975, 185; Ricoeur 1976, 76)

As it is impossible to avoid the hermeneutic circle in interpretation it has to be present also in the hermeneutics concerning man. A circle develops, because the being and its meaning has to be known already before that being can be defined from which the meaning of being is to be made clear. (Heidegger 1927, 5)

With the word "world" Heidegger (1927, 52, 95, 117, 126) does not denote the objective world in a scientific sense, but our personal world in which we live. This world cannot be thought of separately from oneself. Without human beings only beings but not world in the same authentic respect would be. The life-world is more primordial than any objective distinguishing of self and world. Life-world and understanding form indistinguishable parts of the ontological structure of man. The realm of the hermeneutic process – the realm where being discloses itself as meaningful, understanding and interpretive – thus is our life-world. (Palmer 1969, 132) The primordial way of thinking and interpreting the world is not the logical way. Often words are missing, for example when trying the hammer and putting it away without saying anything. Meaningfulness, the connection of action to surroundings (Heidegger 1927, 87), finds its foundation deeper than the logics of language. It is part of the life-world. It cannot be given to things.

Each individual is affected by the original reference to "where" or "why". Essentially an individual acts because of others. Her actions are meaningful because others have so decided. This does not mean that action would be meaningful only if others accept it. Action is meaningful, when in the connection in question others accept it as possible behavior. Actual understanding as a project leads to the future. The human being understands herself through her everyday doings, she meets with things to care for and the possibilities they offer. The particularity of existence understood as disclosure of being can according to Heidegger (1927, 350) be expressed with the word "care". We "care" about the world. We feel on one hand committed to care about the past and on the other hand we care for the possibilities of the future. Care is a primordial, integrative phenomenon that already is existent in the totality. The being of man is disclosed as care. (Heidegger 1927, 121, 191)

The relation to other people mirrors the nature of care. This care can take place in two ways. When man undertakes to carry the burden of another, the other is deactivated, becomes completely dependent and uncouraged. Another way of caring is to even the road for the other in order to allow her to herself complete her own possibilities. This is authentic care, because it gives back the burden of her own worries to

the other. Here real friendship has its ground. (Heidegger 1927, 117-125) From the changing future and the care about future all the informative relationships of man grow, and from them the extent of meaning generally grows, and the birth of the ownmost I becomes possible. Future and past are connected to each other, man always returns from the future to that which was. Authentic future means hurrying beforehand to the last possibility, which also opens other possibilities.

The human being needs contact to other human beings. She does not live passively or by chance, but she creates and destroys, loves or hates. She is productive; she can use her skills and, guided by reason, realize her natural possibilities. She is rootless, but can identify herself. "I am I myself". She looks for meaning in life. The state of language is closely connected to being-in-the-world-together. According to Heidegger the human being is in language in the same way as she is in the world. Man lives in a world formed of meaning. Speech and sentences are special events of language, but they do not form the wholeness of language. Also gestures and expressions belong to language. The world unremittingly talks to man. Thus man continuously argues with the world. To talk means to disclose (Heidegger 1957, 200).

Communication is not only transformation of experiences, believes or opinions from one isolated individual to another, but also togetherness assertively shared in dialogue. To discursive use of language both listening and silence belong, the common ground for the two being understanding. Only if one already understands one can listen, talk, or be silent in a meaningful way. On the other hand language and meaningfulness are guarantees for our understanding of each other. We are thrown not only into the world, but also into language. Language is always before us. We grow together with other people. This coalescent meaningfulness defines our relations to the world. (Ricoeur 1976, 36, 80, 88; Palmer 1969, 132)

Character of understanding

The young Schleiermacher defines hermeneutics as the skill to understand someone's speech properly (Palmer 1969, 92). It is the art of understanding, of performing an interpretation in dialogue with the text. A century later Heidegger (1927, 398) develops his existential hermeneutics around the fundamental structures of understanding and self-understanding, being and to-be-there.

The personality of a human being is formed by disposition and character. The character is dynamic and adjusts to the situation. Heidegger speaks about the attuning of the to-be-there (1927, 134, 140-148). Because of this attuning the human being has an individual way of action, she is able to choose among incitements, form conceptions and make decisions. The way of accepting her own culture opens up with this help of the dynamics. The social attunement of the human being, the core of disposition, is common to human beings belonging to the same culture.

Attuning and understanding are equally primordial and always appear together. Attunement is connected to a special way of understanding oneself and the world. Attunement thus influences how human beings experience their being in the world. It opens the door to facticity, to this that I am and must be (Heidegger 1927, 136, 265). Understanding on the deepest level answers the question "why", whereby the world opens up as a behavioral totality. In the being of man the question is not about an explanatory understanding, but about an ability to be. Here the skill to choose a project of life, a plan for the future, is questioned. Even if one can choose freely among the possibilities, there is only a limited amount of them. The freedom to which a deep understanding opens the way, is thus a freedom to choose a project. The choice of a project, however, limits the amount of possible projects in the future. (Heidegger 1927, 188, 176)

How well another person can be understood always depends on how well one is acquainted with that person and to which degree it is possible to coalesce with her world of thoughts. Because all individuals have their own paradigms complete understanding can never occur. Language also

limits the possibility to understand. Discourse is a necessary means to achieve understanding. A critic cannot achieve an objectifying conception about a work alone. A community of discourse, where critical discourse is practiced, is needed. Then language does not only mediate meaning but also works as a means of self-reflection. Such a discourse is, when it takes place in a casual situation, an open and rational communication. (Bohm 1998, 33)

Man can understand himself only through understanding others. His existence is always in a world shared with others. The others are similar to him. To be is to be together. Also the knowledge of self has its foundation in being together with others (Heidegger 1927, 118). Thus the ones also-being-here, who strive for a common goal, do not hamper each other's existence, but reinforce it. The world of man is a world of togetherness.

Deep understanding is never a subjective attitude to a definite object, but is dependent on the impact of tradition. When looking at a work of art a new world opens up in front of us. As soon as we do not look at the work as an object but see a world through the work we understand that art is not sensation but knowledge. When we meet art the horizon of our own world and our self-understanding widens. We see the world in a new light. A work of art thus cannot form a closed world of its own. It succeeds in illuminating our own self-understanding even at the moment of comprehension. When we meet a work of art we do not move to a different world and we do not step outside time or history. We do not escape from ourselves or from the inartistic. On the contrary we are present to the highest degree. (Palmer 1969, 159)

The hermeneutic awareness is incomplete as long as it does not consider the limitation of hermeneutic understanding. When one tries to understand foreign cultures or ancient ages, it is in principle possible to define the kind of knowledge one needs in order to improve or perfect the understanding of the text. But if the text is systematically distorted, then the limits of hermeneutics are reached. Such a situation is encountered when individuals involved in a dialogue do not notice that the communication connection is broken. Only an outsider may notice that the individuals are talking at cross purposes. Such a pseudo-communication brings

forward misunderstandings that cannot be recognized in the light of the false concord of understanding. (Bleicher 1980, 190-203) As long as we move in the region of the natural languages we cannot leave our roles as reflecting partakers in communication. Therefore we cannot decide when we are submitted to pseudo-communication either.

Self-knowledge, reason and imagination, these qualities of man raise him over animals (Heidegger 1927, 48, 56), but at the same time make his life inconsequent and wandering. The way of being of man in itself is the way of disclosing the world and the own to-be-there in language. To-be-in-the-world presents itself as discourse, the relational whole of understanding is disclosed in words.

4.2.2 Phenomenography in action research

The human being is regarded as a hermeneutic being that tries to understand what she sees, hears or reads. Through the educative process human beings become members of the discursive society. There is some message, someone says something and someone else tries to understand the message. Thus learning is dependent on how the human being as a cultural being manages in interpreting the message she gets and to give it a purposeful content. A society where the individuals can read and write is completely dependent on the ways in which this social knowledge is transmitted. The individual thinks, feels and lives with the language and through the language. She does not experience phenomena or things as they are; she experiences them as products of the social culture. She acts under special circumstances and this either leads or fails to lead to definite mental and practical activities. (Säljö 1996, Bliss and Säljö 1999, 4)

The aim of phenomenographic research is to describe phenomena such as they are subjectively conceptualized. An investigative character is connected to the descriptive approach. This feature appears both when collecting data and when analyzing them. (Bowden 1996, 55) The way of experiencing or understanding a phenomenon says as much about the phenomenon as it says about the understanding subject. As definition can thus be considered a qualitative investigation of different conceptions

about the surrounding world such as they appear in the individual thought process. Phenomenography can be distinguished from other research on conceptions through showing its interest in the differences of content. Thus the concept of conceptions is connected both to the holistic features of the phenomenon and the fundamental differences of the conceptions about the same phenomenon. The researcher categorizes the conceptions according to their meanings. In order to explain the different conceptions she then gathers the categories to higher-level classes of meaning. (Bowden 1996, 60)

Interviews are mainly used for data collection. In this way it is possible to investigate conceptions about previously defined phenomena. In the interview the researcher can assure that the actual phenomenon is discussed at the given occasion and can thus make comparisons that might be difficult to make from a spontaneously arising situation. An interview also allows following up and clarifying expressions used by the interviewed person. (Bowden 1996, 55) Such a possibility is not present when doing observations or when using already existing data, for example official documents. Where spontaneously expressed conceptions from observations or documents exist, the degree of exactness, richness of detail and vividness of the data is problematic. This influences the possibility to ascertain grounded interpretations of the content of the conceptions. Marton (1988) pronounces the nature of the phenomenographic interview as both an intersubjective and a goal minded social construct. The researcher must plan the way to reach her goal. This goal should be kept in mind during the whole research process. This concerns phenomenography as well as other research approaches. In general in phenomenography the interview is started with a question planned in advance. Typical are either questions concerning the solution of a specified problem (how?) or questions about some definite phenomenon (what?). (Uljens 1996, 108) The first kind of interviews is mostly open, so that the interviewee can find the most relevant perspective to approach the problem from her viewpoint. This is important at the stage of analysis, where different perspectives and ways of understanding the phenomenon in this same context might appear.

The interpretation and analysis of data is explorative. One finds the content of the conceptions from the material. The way of dealing with data contains the analysis of and differentiation of utterances and the forming of definite, relevant categories. The approach of the analysis is limited by the content of the concept under which the interviewee understands the conception. The concept concerns the holistic nature of the phenomenon. This means that the starting point of the analysis is found inside the limits of the concept of the phenomenon and not from the total amount of data. Utterances that are not connected to the phenomenon, as delimited by the interviewee, are bracketed. Among the utterances that concern the phenomenon such that define the main components or the main perspectives and the nature of connection between them are chosen. Utterances that concern special, peripheral or less important features of the main components of the phenomenon are not included in the description of the conceptions. (Uljens 1996, 119; Säljö 1996, 29; Marton 1982, 5)

The analyticity of the research approach is seen most clearly in the resulting descriptions and the forms of these descriptions. They are usually given in the form of categories. The investigative feature of the research is seen in that these categories are the main result of the research. This is a difference to less investigative research, where the categories often are starting points for the research and thus defined beforehand. The direct, open form of categories is not important, but rather the short, abstract and reflecting descriptive features in connection with grounded utterances are studied. Often comparisons of conceptions and features of different groups of conceptions implement the descriptions of the conceptions. (Uljens 1996, 119; Bowden 1996, 60)

When a phenomenographical researcher has interpreted the conceptions, she decides what theoretically meaningful and interesting contents they might have and forms the categories. Thus the theoretical background of the researcher helps her to decide which conceptions should form categories of meaning. The categories can further be connected to wider categories on a higher level. These then form the new theory of the researcher. (Marton 1987, 34)

The phenomenographic approach tries to answer the question how knowledge and understanding of students could be included in the investigations. Knowledge depends both on reflection and context. Reflection is constantly changing and thereby causes the learning context to get a new content. (Marton and Tsui 2004, 8) When trying to find conceptions about some phenomenon, one tries to hit the core of meaning in the utterances made by the investigated individual. The conceptions are, however, there as such and thus independent of from whom they stem. (Marton 1996, 182; Bowden 1996, 60) Phenomenography does not group individuals in accordance to their conceptions. Such an aim could, however, give the researcher the possibility to distinguish individuals with different styles of learning in a general way. From this a result could be that the reasons for such differences could be found. This would demand descriptions that could be found repeatedly in different learning circumstances and learning contexts. (Francis 1996)

In my study I have used clean phenomenography. However, after finishing the analysis and presenting the interpretations I have gone back to the original interviews and attached the teacher pseudonyms to the utterances. In this way it is possible to gain an insight into the validity of the study.

In this chapter I have laid the foundation of my research process by presenting the methods I will use in the data analysis. The interpretive method here forms the structure of the action research process, which also includes phenomenography. According to Denzin "interpretive research enters the hermeneutic circle by placing the researcher and the subject in the center of the research process". In my study a double hermeneutic or interpretive circle is implied. The subjects who tell their stories are, of course, at the center of the events. The researcher who reads and interprets their stories is at the center of her interpretation of those stories. The two interpretive structures interact. The two circles overlap to the degree that the researcher is able to live her way into the subjects' "experience stories and self-stories. These circles will never overlap completely, for the subject's experiences will never be those of the researcher." (Denzin 2002, 354)

5 Empirical investigation or A small narrative about some learners

At the end of year 2001 at a competition in science and technology for secondary school students I became involved in a discussion with some other teachers over a cup of coffee. We knew each other only slightly as we worked at different schools in different districts (Kirkkonummi, Espoo and Helsinki). But as we were talking we noticed that we had some concerns in common. Especially we thought that it was a waste of time and energy that each physics teacher should have her own set of experimental tasks for her students. It would be very purposeful to collect experimental tasks into a pool that all teachers of physics could use. I and another teacher decided to start such a work. Back at our schools we talked to our colleagues about this idea. Some of these were interested to join us. A date for a first meeting was agreed upon.

Rather soon we noticed that in some way we would have to delimit the area of application of our work. At our meetings we discussed the new national curriculum that would come into use in Finland not later than in the year 2006. According to this curriculum physics and chemistry would be taught as separate subjects in grades five and six in primary school. Earlier these subjects had been included in the environmental and natural studies. In general we discerned that teachers both in primary and secondary schools were concerned about the implementation of the new curriculum. The subject teachers in secondary school felt that the most interesting parts of physics and chemistry teaching now was taken away from them and shifted over to the primary school teachers, who often had a poor knowledge of physics and chemistry. In the primary schools the teachers were afraid that they would have to give up part of their teaching positions to secondary school subject teachers. Also books and teaching materials for the primary schools were lacking. Here was indeed an open space that needed to be filled and a problem that needed solving.

We decided that the need to prepare laboratory tasks for grades five and six was urgent and should be the starting point of our work. Thus we were able to delimit our original goal in a natural way. We invited a primary school teacher to join our group. The primary school teacher's help was important, because the intelligibility of the tasks was not always taking into account the vocabulary and level of development of the young

students. Also the primary school teacher could test the tasks in her own class. The aim was to make the experiments easy enough to be performed in ordinary classrooms without much equipment.

We made the approach in the experiments problem based, because we thought that it would be a good method for teachers with none or very short studies in physics and chemistry. To use problem based learning (PBL) (Stepien and Gallagher 1993; see also Dumbrajs 2000; 2001, 21), where the teacher has the role of facilitator, can be a way to conquer difficulties due to little subject knowledge (Barrows 1985, 108).

In accordance with the national curriculum such work that builds on the activities of the students and on collaboration between the students should be emphasized. The learning process should proceed from observations of different phenomena and, via structuring of basic concepts, reach every day application of the acquired knowledge. Problem based learning as a method fulfills these conditions. The teacher then functions as a guide and catalyst in the students' search for knowledge. Problem based learning includes three important components: 1) Learning takes place in collaborative groups, 2) the students themselves regulate their learning, and 3) the learning strategy is problem solving (Dumbrajs 2000; 2001, 21). At the beginning of the period of instruction the students get the starting point or the concept, which defines the content of the study, and possibly the goal. They themselves formulate the problems to be solved in their groups, reflect over possible solution methods, and finally solve the problem. In the experiments the students examine and describe phenomena rather than that they are being taught the theories about them. In this way the teacher does not have to be able to explain very much. The model recommends that a tutor or expert visits the class and answers questions made by the students, occasionally contributes with lectures and/or help to resolve awkward problems, and perhaps make some demonstrations in order to further explain the phenomena.

We named our project PLOT (Problembaserat Lärande Och Tutorskap, Problem based Learning and Tutorship) in acknowledgement of our application of the above model of problem based learning. The purpose and goal of our work shows features of action research in looking for

changes in activities and practices, discourse and communication, and social relationships. "The cycles of work of a teacher for example, will intersect with the action research the group does on its own learning and on its collective action to change the educational work of the school, system and community. The teacher's work will also intersect with cycles of work of students engaged in action research into their own learning, …" (Kemmis and McTaggart 1988, 18). In such a process an evolution of the teacher's understanding will take place as the new practice is developed and implemented.

5.1 Data collection

My approach to human learning and development is socio-cultural. Thinking is interpreted as a process one takes part in and cognition as a development between individuals involved in common activities. My research questions are presented in section 4.1. They interrogate how subject teachers answer the request to learn how to teach class teachers and students in accordance with PBL material developed during the process, how students experience their problem based learning in collaborative groups and how primary school class teachers react to teaching as facilitators in a PBL context. Special interest is devoted to the question how teachers understand the team concept. The experience of working and learning in a team and the possible development of the teaching and learning process are considered.

I collected data for this investigation from different sources and by many different means. For the investigation of teams, as a first step I interviewed two subject teachers that have worked closely together for many years, but that did not take part in the present project. This pilot stage gave usable hints about the information open interviews could supply.

The PLOT members answered a questionnaire (see Appendix I) after they had worked together for about half a year. The group (N=5) then consisted of a young class teacher, who had been teaching only one and a half year, three experienced subject teachers, including myself, (experience 10 – 30 years of teaching) and a subject teacher with two

years of experience. One of the experienced teachers was a male teacher. Thus we formed a rather heterogeneous group. At this time the team worked with the laboratory tasks for students in grades 5 and 6 and with the guides for primary school class teachers. Later, when the PLOT group had worked together for close to two years, I asked the members in open interviews about their conceptions of a team. After three years of working together, when the work came close to an end, I asked in open interviews what they had gained as teachers and as individuals from their work on the PLOT project. I also audio taped one of the later sessions of the team.

Two of the workshops (see subsection 5.4.2) organized for the primary school teachers I audio taped and one I partly video taped. The primary school teachers also filled in a questionnaire at the beginning and end of their first participation in a workshop (Appendix II).

The students in grades 5 and 6, who tested the laboratory tasks, noted down their thoughts and questions. Copies of these notes and copies of their logbooks were supplied. A quite special sort of experimental material consisted of a whole class of 6th graders from Vindängen's primary school in Espoo. This class had taken part in the testing of the laboratory tasks, and was still kept together as a class when the students arrived to secondary school. These students went on to learn according to the PLOT model. I frequently audio taped their discussions and their logbooks and other study materials like mind maps, tests and examinations I included in the data collection. In order to supply material for comparison, a parallel class, where the teacher did not use the same method of instruction, took part in two examinations that I developed for the PLOT test-class.

A summary of the different data sources and materials is shown in TABLE 2. In the following sections the analysis of the data will be presented together with the results.

TABLE 2 Data collection with timetable and implicated use of the data

PLOT members (4 subject teachers, including myself, and 1 class teacher) (N=5)	Questionnaire early autumn 2002	Background information
	Open interviews autumn 2003	Team conceptions
	Open interviews summer 2004	Gain of the project as teachers and as individuals
	Audio taped sessions late autumn 2004	Discussion and future plans
	Observation 2002-2005	Change and development
Class teachers (N=14)	Questionnaire autumn 2003	Background
	Two audio taped workshops 2003 and one video taped workshop 2004	Science conceptions and opinions about pedagogy
Students	Logbooks, written notes, mind-maps, examinations and other study materials 2002-2003	Learning in groups, influence of prior knowledge
	Audio taped lessons and examinations 2003-2005	Development of team features, learning as team
	Observations 2002-2003	Social competence
Pilot stage, 2 subject teachers	Open interviews spring 2003	Team investigation

5.2 What is a team?

The method of working in groups has been used as a motivating and engaging way of learning.[13] Glasser (1985, 95-117) has assessed working reports from several teachers using cooperative learning in their classes. According to his study students develop both individual responsibility and collaborative skills. The oral activity promotes the skills to discuss

13 In the following I discuss those parts of theory that were of relevance for the action of the teachers in the PLOT team. This theory forms the plot of my narrative.

and argue at the same time as a deep knowledge is formed. The group of students develops qualities that are characteristic for a team. The students "commit to take the risks of conflict, joint work-products, and collective action necessary to build a common purpose, set of goals, approach and mutual accountability" (Katzenbach and Smith 1993, 85). But not only students learn at school. Also the teachers can use cooperative methods to develop their teaching. There are many activities at school where teachers form groups, for example when planning and developing curricula, planning for school celebrations, or taking part in work conferences. In some circumstances such groups can exist for some time. However, such a group seldom develops into a real team. Working groups or groups involved in teamwork rely on the sum of individual accomplishments for their performance. They pursue no collective work products requiring joint effort.

A team constitutes a system and can be defined as a stable group of individuals, who themselves regulate their actions. The team takes responsibility for its work that is done in close collaboration between the individuals. The differences between the members are used to enlarge the region of competencies of the team. The members of the team pursue common goals and visions with the help of common rules of action. (Katzenbach and Smith 1993, 45) Cooperation cannot be achieved by force. An ongoing process of adaptation and never ceasing interaction between the collaborating individuals is needed. A group can be seen as going through four stages of development during its unfolding to and existence as a team. In the beginning, as a group, it leans heavily on the performance of individual members. No collaborative work takes place. By choosing to try to form a team the members are binding themselves to taking risks of internal conflicts, to trying to achieve results in collaboration with each other and to reach common goals in common responsibility. As a potential team it will always meet hindrances on its way. These must be conquered by concentrating on the binding vows one has taken. If it is not possible to concentrate on the common goals of the team or if such goals do not exist, then the team will become a pseudo-team. Such a team might work on developing trust and mutual interdependence between its members, problem solving skills and collaboration, but it has forgotten the importance of a performance goal

and the mutual accountability. If, however, the common performance goal always is kept as a lodestar in front of the performing team, there is a good chance that this potential team will develop into a real team. Slowly the capacity of the team grows and thereby also the members' trust in their team. The team now performs well. A high-performing team is denoted by the strong commitment the team members feel to each other. But no team will last forever. One day it will break up or transform, for example by taking up new tasks and/or accepting new members. (Katzenbach and Smith 1993, 84)

It has been noticed that a team performs at maximum if the self-regulated work concerns problems which the members themselves have an interest in solving. It is characteristic for an individual who herself regulates her work to be open for new ideas. She pursues authenticity by taking responsibility for her own solutions and by choosing her own potential possibilities (Nichols 2000, 10) She thinks in an independent way and forms her own opinions. Such an individual shows initiative, keeps to plans and conducts herself positively, openly and is questioning towards the world around her. She looks at her world as at an interconnected system of which she is a part. She can use information in a purposeful way; she masters surprising situations and can give reasons for her opinions. Knowledge begins and ends as individual human understanding. However, in a team knowledge is collaborative. You have to share your knowledge with the other team members. You have to put the goals of the team in front of your own goals. "Joining a team is a career risk, giving up individual control is a performance risk" (Katzenbach and Smith 1993, 129). Taking risks is a necessity in order to form teams. Real teams always find ways of using their members' requirements to distinguish themselves. Each member is complementary to the others just because of her special qualities. When working in a team one has to give something of oneself to the other members of the team. Collaboration cannot occur if this wish to give of oneself is missing. As a present in return one gets the cooperation of the others.

Learning in a team is produced by individuals. When an error is detected and corrected without questioning its reasons, the learning is said to be single-loop. A thermostat is defined as a single-loop learner. It detects

states of "too cold" or "too hot" and corrects the flow of heat accordingly. If the thermostat would ask itself why it was programmed in this special way, then it would be a double-loop learner (Argyris 1992, 68). Team-learning does not occur when a new problem is formed or a solution is invented. Only when the invention is produced and either is successful or fails one can say that learning occurs (Figure 3).

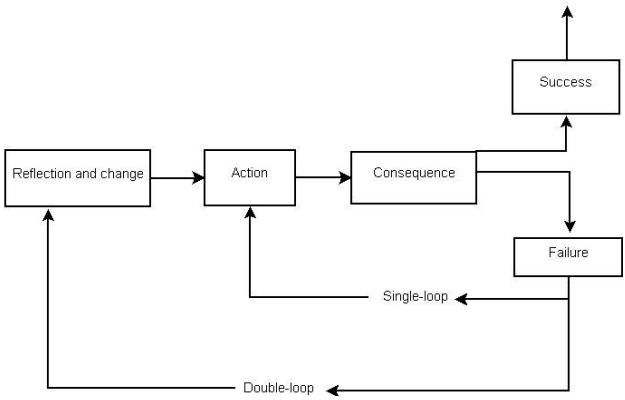


Figure 3 Single- and double-loop learning. Reshaped from Argyris (1992, 68)

5.2.1 A successful team: a pilot stage

In order to get a concrete feeling for features that distinguish a team from a group I interviewed two teachers from my school, Mattlidens skola in Espoo, who to my mind, and according to the definition given above, formed a real team. Also, I wanted to find out what kind of information could be expected from an open interview and, of course, get some training in conducting an interview. The interview material was collected in the spring term 2003. The interviews took place in the school during breaks between lessons. Thus it was important to find a peaceful corner where I could audio tape the stories, which each interviewee told independently and without knowing the story of the other. I transcribed the material. The interviewees read the transcriptions and were given the opportunity to clarify and change their accounts. Thus we could

agree on the content. In reading the text I could still hear the voices of the interviewees in my ears. After the interpretation of the stories I again discussed my results with the interviewees and we agreed on the conclusions. Below follows the story of a successful team.

Two subject teachers in Mattlidens skola in Espoo, Karin and Rosa, worked closely together for many years. Now Karin has left Mattliden for a position in another school. Both teachers teach languages, Karin Finnish and German, Rosa German and English. They are of the same age, in their forties, Karin is single and Rosa married, having several small children. In an interview Karin defines their characters as follows:

> *Karin: Yes, we are in a very positive way complementary to each other…. Rosa is the pedantic one and I am… a bit..*
>
> *Interviewer: … sparkling..*
>
> *Karin: … idiotic ideas that she tries to take down on earth…*

From the above it is clear that Karin and Rosa worked well together partly because they enlarged their region of competencies. Also from their working methods, which Rosa described, it is seen that they had much to give to each other.

> *Rosa: … that we are thinking about it at the beginning just by ourselves. And then it is… me, who says, that now…. We have thought enough. And then we sit down to work. And then we have…. lots of ideas. Then we first play a bit. One of us gives something and … and the other is filling in and…. And… and in this way. And thus we get results.*

Their work included normal teacher's work, preparing lessons, giving tests and making assessments, but also they worked with the curriculum for foreign language education. However, they had one project that they themselves in a self-regulated way had included in their goals and visions. This was the portfolio-project. A portfolio can briefly be described as pieces of work that the student collects from different subjects and that follow her through the grades (Danielson and Abrutyn 1997). These pieces of work should express her most valued abilities, interests, and self-identities. The student can thus reflect over and follow her own development and the teachers and parents can follow her process

of learning. Rosa described how it came about that they started this project:

> *Rosa: Öh… Karin wanted… that we should start working with the portfolio. She was very interested in this. She had got the idea from some course or other that she had attended. And so she started. The thought. Then we were thinking about it for rather long. Like we are also doing, when we shall have an examination or something…*
>
> *Karin: It is surely interesting. (laughing) When we are working together…. One of us gets an idea and the other starts to formulate and then the other way around… it is just like…in some way… We play with ideas and then one starts like… formulating and producing, like it is really rather fun how we have….*

The project was included in the curriculum of Mattlidens skola from the beginning of the school year 2003-2004. Rosa and Karin have been responsible for the implementation of the portfolio in all grades. Now also the primary schools in Espoo implement the portfolio.

Why was Rosa's and Karin's team so successful? They themselves thought the reasons were the following:

> *Rosa: Well, I think the difference (to other groups) mostly lies in that… Karin and I… like … formulate the needs and goals ourselves … for what we want to get done. We have a clear vision … because we… try to … work in parallel all the time… so we always have a clear goal in front of us… from our own needs….*

Karin and Rosa fulfilled the most important of the criteria to be a team, they had a clear purpose. They also worked in a self-regulated way and they enjoyed working together. They showed both individual and mutual accountability in their process of work.

5.2.2 How do teachers understand the concept of team?

The group of teachers at the time, when the work on the laboratory tasks started, included Vera from Kyrkslätt högstadieskola, Rolf and Sibban from Mattlidens skola and Moa from Vindängens skola. Moa is a primary school class teacher, the others being secondary school teachers of physics and chemistry. As the teachers were not all acquainted

to each other, relatively much time was used telling about one's own thoughts about the situation and about teaching at large. It was realized that this was a very important phase for everyone involved. The skill requirements for an effective performance include that the interpersonal understanding and the purpose of work can arise through effective communication and constructive debate. The interpersonal skills include risk taking, objectivity, active listening, and questioning, supporting and recognizing the interests and achievements of others. Taking this into account the teachers found a common model according to which to work. The purpose of the work was shaped and reshaped as a response to the possibilities opening up in front of the group of teachers. Meaning was created during these discussions. The problems to be solved and possibilities and hindrances to be faced were identified and decisions on how to move forward were made. - Around one year later Moa handed over her responsibilities in the team to her colleague Lotta because of maternity leave. Two other new members, Lena and Michaela, joined the team. Lena is a young subject teacher with a few years of teaching experience and Michaela has retired from a position as subject teacher a few years ago.

In the autumn term 2003 the teachers in the PLOT project involved in the preparation of laboratory tasks in physics and chemistry for grades five and six were asked to explain what their understanding of a team is. They had then worked together close to two years. The interviews were performed independently from each other. The accounts were audio taped and transcribed. The teachers could comment on the content of the transcribed interviews. These comments were taken into account in the interpretation of the data.

Rather different aspects on the interpretation of the concept team were presented. Some teachers saw the work in a team and a group as almost equivalent. When the interviewer prompted them to find a difference, they mentioned the purpose of the work in a team as distinguishing teams from groups. Others had a clear view of a performing team with a vision and common goals. The teachers' accounts were analyzed using phenomenographic methodology.

TABLE 3 Code words and frequencies of the transcribed interviews.

Code word	Frequency
equality	3
goal	3
group	21
knowledge	9
leader	10
others	24
positive	12
reflect	53
school	4
self-directedness	1
student	4
teacher	9
togetherness	31
work	31

The program QDA Miner was used for a first coding and labeling of the material. This program was allowed to make statistics over all words appearing in the transcribed material. The groups of words with seeming relevance for the present investigation that appeared in the material are shown in TABLE 3. Utterances that contained a code word were labeled with help of the program. The same utterance could appear under more than one label. The utterances in the separate groups I read many times trying to find some structure. Soon I noticed that the groups "togetherness" and "work" were closely connected. I combined them under the label "performing together". Part of the utterances under this label I shifted to those under the label "others", which then was relabeled as "individual differences". The utterances under the labels "positive" and "reflect" partly went into the group labeled "performing together". The rest got a more accurate new label: "dialogue". The utterances under the labels "leader", "teacher" and "self-directedness" I combined under the label "leadership and self-regulation". The utterances under "equality" went into the group labeled "performing together" as did the

utterances labeled “goal”. The utterances in the groups labeled “school” and “students” I found not relevant for the investigation.

As a result a category labeled “group” became clearly distinctive. The other evolving categories concerned team features. Only the category labeled “knowledge and learning” contained contributions that could be ascribed to both group and team features. As lower level categories five distinct subjects emerged, namely performing together, self-regulation and leadership, individual differences, dialogue and knowledge and learning (Figure 4).[14] These lower level categories will be discussed below in this subsection.

In the main category “Group” the individual asks herself how to accomplish a given task. The work is seen as the sum of what each individual can contribute. The main category “Team” involves adaptation and collaboration of the team members to perform together for a common purpose (Koslowski et al. 1999, 241, 242).

14 To make an example I take one utterance with the code word ”work” and two with the code word ”together”:

A. … and we all worked in rooms next until one another. And this meant that we … we shared material, we shared knowledge, we could work with open doors. We … we learnt (laugh) to understand each other just by looking at each other, without saying anything. (Michaela)

B. But it is characteristic, I think, that there is a common goal and tasks to perform together, at any case … (Rolf)

C. …or in teams generally that individuals are a bit inhomogeneous, then the idea is, of course, that one should enrich each other, like in this team. … […] … But still we have, of course, a base … that we have together; otherwise it would not at all function… (Rolf)

As a first step these utterances all came into the category ”Performing together”. Later the utterance C was shifted to the category ”Individual differences”. All three utterances belong to the main category ”Team”.

Please, note that the pseudonyms attached to the utterances have been added after the analysis was ended and the results written down.

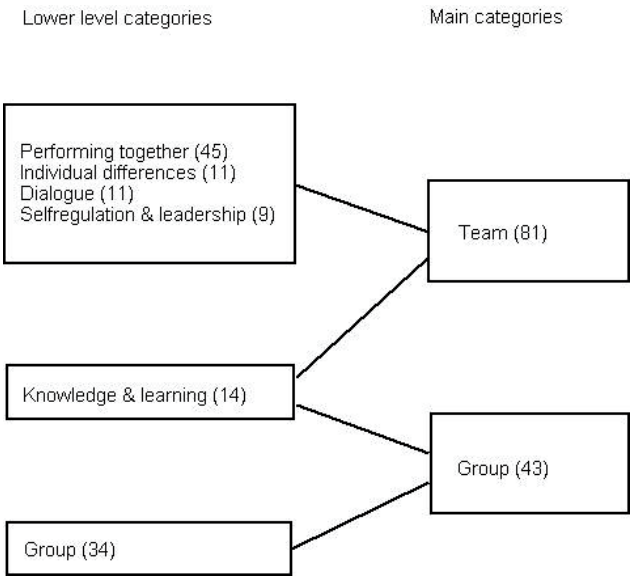


Figure 4. Scheme over the forming of categories. The numbers in brackets give the number of utterances contained in the category.

When thinking on the team as a group of individuals, the teachers had in mind the groups of students, either the whole class or a smaller group, and of teachers, either the whole staff or a group of teachers working in the same field or with the same task. Teamwork in this sense was seen as a necessity of life. Students should learn to work in teams at school. Education should at least to some degree take place by teamwork. It was realized that all individuals do not like to work together with others, but it should be made clear to them, that this was expected of them. It was seen as important both for those accepting to work in groups and for those opposing it to be forced to do this.

> *- But one has to ... has to make it clear to them that life is not ... like working alone, but life is teamwork. (Vera)*[15]
>
> *- I think it is important both for those that volunteer and those that do not that they are forced to take part in teamwork. (Vera)*

15 Please, note that the pseudonyms attached to the utterances have been added after the analysis was ended and the results written down.

Only occasionally an exception could be made and individual work could be allowed. The intention when forming groups of individuals is that these should learn to know each other and to work together. There should be a leader assigning the tasks for group members. The tasks are mostly individual, the result of the teamwork is the sum of the individual results.

A work team develops as time passes when you work together with others on some task. You will be dragged along and the task becomes interesting.

- And then, if you are part of a team you become interested ... (Vera)

In work teams the members should consider each other as equals, they should work for a common goal and they should help and support each other. The atmosphere in the team should be friendly and accepting.

- And some sort of sharing the work, to meet, after the tasks have been decided upon at some meeting and after the members have done the work individually, to discuss the results. (Rolf)

The work team can be of a permanent character. The tasks of a work team can change with time. Permanent teams at school are the teams that organize celebrations, sports events, charity happenings like collecting money for the hungry or for a "shared responsibility" foundation, the "treatment of conflicts and crisis" group and the leaders' group. In these teams the same members work year in year out. A new member is accepted only if an old one leaves the school, or if someone of other reasons, for example inner conflicts, leaves the team.

A real team can develop through common experiences that are of importance for the performance.

- If we think of the situation when we went to Athens [for a conference], there we had the beginning of a real team in a sense. (Michaela)

The members of a real team know each other well; they understand both each other and the significance of their task.

- I mean … I mean how gallantly the tasks of work were divided up…Ok… you do this and Lotta does that and can you be in that classroom… and

ok, we go over there… I mean … this shows in my opinion how it is in a team. (Lotta)

A never-ending dialogue gathers the different interests and opinions of the members to a paradigm of the team. The work of such a team can last a long time. It is seen as unique that a real team can create an atmosphere of continuity and development over several years. There are some features that teachers think especially distinguish a real team from a group. They think that the work should be collaborative and that all the team members perform to reach the common goals. They like to keep a dialogue going in which they can develop their own opinions and get new ideas from each other.

- When you get an interest.. and everyone is interested, then you develop a pleasure in work quite automatically. (Lena)

In the team there is a strong feeling of belonging together. But the teachers also think that the members should be of different age, have different perspectives on the problem, have different educational backgrounds and different situations in life. This heterogeneity creates richness in the team.

-… and I also think that a team profits from its members' different ages. And different situations in life, if one can say so … (Michaela)

Real teams at schools are usually found among teachers teaching the same subject.

In a top performance team the members feel a deep commitment to each other and to the task.

- We worked with the curriculum, we discussed disciplinary questions, we discussed about our subjects, we discussed about general structures.. … I dare to claim that our work had extensions everywhere. (Michaela)

The problems of the school were the problems of this team. The vision was to build a better school. The challenges of the team, however, originated in the own teaching and the development of instructional methods. A common commitment is noted in the description of instructional situations.

> *- … and further on we all worked in neighboring classrooms. And this led to … that we shared … we shared equipment, we shared knowledge, we worked with open doors. We learned (laugh) .. to understand each other by only looking at the other, without saying anything. (Michaela)*

In a top performance team a common understanding reigns in the work context.

> *- The way of understanding each other, the other's way of thinking. And .. and in the end reach so far that one does not fear to tread too close to the other.. but we work together. One can … (laugh) … can freely express impulses, one can present ideas and one knows that the other is not thinking that one is treading too closely, or something like that, because all is open. Then you have reached a perfect situation… (Michaela)*

A top performance team, however, demands everything the members are able to give. The members sacrifice their personal free time and hobbies; they work day and night even without expecting any other acknowledgement than success in the performance. The family is forgotten; there is a new family, the team, that means all to them. It is clear that such a team can exist only for some time. When the mission is fulfilled, the team disintegrates. This kind of team is seldom found at school. Perhaps in connection to a change process, for example, when implementing new teaching methods, one could imagine that a real team would change to a top performance team.

In accordance with the opinions expressed above I can now define the team as the teachers conceptualize it with the help of a square diagram (Figure 5). This diagram that describes a holistic view of the team concept evolved from the data. On the horizontal axis I picture the permanence of the team and on the vertical axis the strength or articulateness of the vision. A team that fulfills a different purpose inhabits each of the four squares. There are also other ways of picturing the team conception. For example Willman (2001, 192) has investigated the team conception of class teachers involved in teamwork. He found five interpretable repertories: companionship, practice, group, work community, and hurriedness. These all have an inner dynamic that allows different team features to develop.

Defining the team construct is of importance when a team is formed (Wilemon and Thamhain 1983). It establishes the boundaries for member activities. It also identifies the mission of the team. The work group is defined by the primacy of tasks or tools. Unlike crews and taskforces membership in work teams is more or less permanent. The completion of the work relies on member characteristics. The production teams we find in enterprises configuring part of the infrastructure are examples of work teams as described by e.g. Pirnes (1996, 101). Members of a work team are interdependent. Katzenbach and Smith (1993, 47) see concentration on performance as essential for real teams. For good team performance technical or functional skills, problem-solving skills and decision-making skills are necessary. Such teams are the process teams in an organization. In a top performance team the members do not feel commitment only towards common goals and purpose but also towards each other (Katzenbach and Smith 1993, 85). Top performance teams are project teams that exist for the time needed to accomplish a certain project.

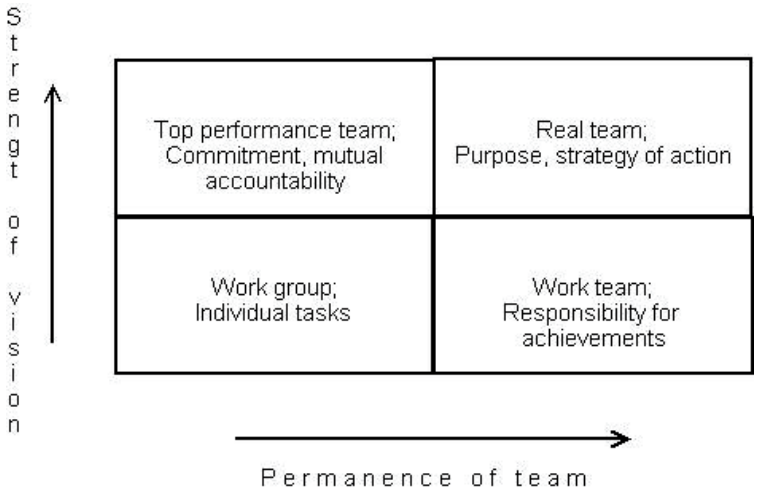


Figure 5. Diagram over dependence on visional strenght and on permanence of different types of teams

When teams are investigated their development is usually of interest. Therefore, when organizational team systems are investigated, the study is often limited to one type of teams. For example Pirnes (1996), Huusko (2003) and Mäntylä (2002) have studied work teams and their development in the direction of real teams, whereas Katzenbach and Smith (1993), Nonaka and Takeuchi (1995), Belbin (1993) and others often concentrate on the development of pseudo-teams to real teams and finally to top performance teams, i.e. they are then interested in process or project teams. However, in school systems, most types of teams exist side by side. The teachers come into contact with them every day. It is important for them to understand what one can expect from a work team and what a top performance team might achieve.

The PLOT team, to my mind because of being rather heterogeneous, was able to describe the team concept as a totality in a simple way. This would not have been possible for anyone of the members individually. I myself would also have rejected part of the description initially, because of my fore-conceptions. But this is how it is in a team. Together we are more than the sum of the parts.

Performing together

In this study in the PLOT team the following general features of teamwork were recognized: teamwork is collaborative work to achieve a common goal; working together on the same problems may lead to real friendships; important is that the members take care of each other and share the results of their work. The atmosphere in a real team is intimate; you work for the same purpose and think in similar directions. The members use much time to learn to know each other and to understand each other, but also to define and redefine their common goal. They feel that they can lean on each other and get appraisal and feedback from each other. To achieve this stage it is necessary to work together for some time and learn to listen to and consider the others' thoughts and ideas.

> *- And it … if you do it together and try, like … anyhow, we tried in this way to encourage each other and support, like, and bring about …(Rolf)*

In the PLOT team the most negative feature was seen as the circumstance that the meetings took place only every third week, even if this happened regularly over a long period of time. In a real team the members should preferably meet more often. On the other hand the members were happy that they had reached their present goals and felt comfortable and at ease in the company of other team members. They looked forward to new challenges and performances.

> *- Well, I think of for how long and how often we have met. But I also think of the purpose and our goal, too. (Lotta)*

Self-regulation and leadership

In this study, when a group was formed with the hope that it would develop into a team, a leader of the group was necessary. Generally, even if a group is left to itself a leader will emerge from the members of the group. A good leader is important to how well the future team will develop. Her task is to declare the goals and the norms of the team. She should keep the different threads in her hands and with feedback and encouragement help the members in their work. At the beginning of the existence of the PLOT team I took on the responsibility of leadership.

But when the real team developed a leader was not needed any more. All members were equally involved in collaborative work. The dialogue between them, the feedback and help they got from each other and gave to each other carried the work forward.

> *- Let's see.. this I experience ... that everyone has the same ... I think we must be equal. (Rolf)*
>
> *- One .. has may be .. possibility ... to get .. even acknowledgement, but also response on the result of one's own work. This is positive and stimulating. (Rolf)*

Individual differences

Generally the members in a team should not be that similar individually, although some common foundation should exist. They could preferably be of different ages, and have different social and/or cultural backgrounds.

Important is, however, that they can put the shared purpose and the goal of the team in front of their own individual interests. Then the interaction between the members will be more open; there will be more perspectives on the problems and more possibilities available. Different ways of working will influence the members in a refreshing and educating sense.

In the PLOT team three generations of teachers participated. This enriched the atmosphere tremendously. Each teacher felt that she could contribute with quite a special aspect on the problem.

> *- I think that we are complements to each other. (Rolf)*
>
> *- But, but ... we come from many different directions and ... and we are of many different ages. And I think that this also can be a richness. (Michaela)*

Dialogue

A team can function well if the members discuss the problem in front of them and together decide about a good strategy. This was the case in the PLOT team. Also in the case of opposed opinions and quarreling the team members in the end might find a compromise that lead to the goal, as they experienced an equality grounded in trust among themselves. To be able to agree on some possible strategy for arriving at the solution was essential for the survival of the team. In the case that a leader who decides about strategies and tasks for the team is needed, the team members will not be able to devote the same amount of work and interest to the problem they are going to solve. The responsibility would not in such a case have been theirs in the same way. Only teamwork can be achieved under such circumstances, not the work of a real team.

A continuous dialogue interrupted for short periods of reflection on the problem and of self-reflection developed the way of thinking among the team members.

> *- It is not necessary to be of the same opinion always, one should be able to discuss and find solutions and compromises. (Lena)*

Knowledge and learning

In each stage of the existence of a team the acquirement of knowledge is important. At the very beginning, as the group is formed of individuals, it is important that the members learn to know each other and to take the others into account. The individuals with leadership abilities soon learn how to open a dialogue and achieve some kind of teamwork in a group. By explaining a task to the others they themselves understand the demands of the task in a deeper way.

> *- It is like ... always the one, who explains and narrates, simultaneously clears her own thoughts. (Lotta)*

The class as a learning community also includes the teacher. The teacher is also learning from the students. The teacher as a learner is not limited in what she can do by what she was taught as a student. And because the learners are all very different, with different ways of working, learning will take place using many different means. One aim for all is the development into social individuals.

Teachers can learn from teachers. Teachers from primary school took part in workshops organized by the teachers in the PLOT project (subsection 5.4.2). But also the teachers in the PLOT team learned from each other.

> *But then that one meets and goes through and relates what one has done .. and then gets it assessed and discussed .. not assessed ... it might be the wrong word .. evaluated it might be.. or discussed ... and with the help of discussion and exchange of opinions... one achieves ... maybe new thoughts on how to solve the problem and makes changes oneself in the next step of working and reaches a better result, surely, thanks to that dialogue. (Rolf)*

This is a good example of double-loop learning in a team (Figure 3).

Teams always look for new knowledge. The individual members seek opportunities to learn what is needed to get their job done. In the PLOT team two of the younger members, Lotta and Lena, took part in seminars to learn about the demands of the new curriculum.

The members of the team wanted to learn how the problem with physics and chemistry teaching in grades 5 and 6 and the necessary extra training of the primary school teachers was handled and thought about elsewhere. At the same time they wanted to get the possibility to tell about their own work so they contacted the National Board of Education. There a positive view to their method of teaching and learning was taken and it was thought that the method could be of use. The team got financial support to fulfill the wish to organize a seminar on this topic. The Mattliden seminar 2003 gave many new items to discuss and much to consider.

5.3 A self-regulated team in a hermeneutic learning process

All people, students as well as teachers, solve problems and are thus creative. Problem solving is a product of the cognitive function operating within some environment. Learners can be located on a continuum of cognitive style depending on the mode in which they solve problems. This continuum extends from an iterative, nonlinear creative process, represented by a jump into the hermeneutic circle, which develops in a complex and dynamic social system, to an essentially linear way of solving problems.

Teachers performing action research are problem solving. They have a plan, which they want to implement. They act accordingly and observe the results. Reflection on these leads to revisions in the plan, new action and new results in a spiral process. The process is hermeneutic (see section 4.2).

5.3.1 To innovate how to teach[16]

Problem based learning can be seen as a pedagogic method, based on the social constructivist theory of Vygotsky (1962, 103). Problem based learning uses work in groups, discussions, investigative laboratory tasks, students' self-regulated work, lectures, debates and reflections

16 Theory is presented as needed for the plot of the narrative.

as learning methods. A first result can be a claim "I think this is how it is". This statement will be modified according to results achieved in empirical investigations. The modifications bring about new challenges, investigations and further modifications. From the context in which discoveries are made the student proceeds to justify her claim. To achieve this social activity, discussion and communication is necessary. Theoretic concepts arise from reflective abstraction, which implies social contact (Warren and Rosebery 1996). The relations between claims, facts and evidence are negotiated in the group, when different opinions clash.

Problem based learning (PBL) has several distinct characteristics, which may be identified and utilized in designing a curriculum. These are (Stepien and Gallagher 1993):

1. Students are only given guidelines for how to approach problems - there is no one formula for how a student approaches the problem.
2. Reliance on problems to drive the curriculum - the problems do not test skills; they assist in the development of the skills themselves.
3. Students solve the problems - teachers are coaches and facilitators.
4. The problems are truly ill-structured - there is not meant to be one solution, and as new information is gathered in a reiterative process, perception of the problem, and thus the solution, changes.
5. Authentic, performance based assessment - is a seamless part and the final stage of the instruction.

To learn is probably one of the most complicated processes that a human being takes part in. To achieve an effective learning not only the analytic and logic abilities of thought must be involved, but also artistic creativity and affective experiences. If we study "Foundations of the [national] curriculum for the comprehensive education 2004" (anon. b. 2004), chapter 3 "Foundations for instructional practices", we can read in section 3.1 "Aspect on knowledge and learning" that *learning ought to be an active, goal orientated process where the students starting from their earlier knowledge structures work up and interpret the material they must learn*. Further on in section 3.2 "The pedagogical environment" we can read that *the goal is to support the student's motivation to learn and her curiosity and further on to promote her activity, self-regulation*

and creativity by supplying interesting challenges and problems. Under the caption "Methods of work", section 3.4, we can read the following: *The task of the working methods is to develop the ability to learn, think and solve problems, the ability to work and function socially and to active partaking*. These citations support the use of PBL as teaching method to a very high degree.

The innovative aspect of PBL can be located in the combination of educational methods aimed at the cultivation of independent learning behavior and the consequent exploitation of the relationship to actual practice. In supporting an innovative capacity in students and a culture of innovation acquired in primary school, student confidence, independence and leadership skills are not lost in the transition to secondary school. Stagnation phases in learning are then, perhaps, avoided.

The relationship between the members of the group should be communicative. This means that knowledge should be shared. Members look for each other's knowledge, they try to understand each other's way of thinking. Both verbal and nonverbal interaction is used to intermediate knowledge and emotional attitude. To share knowledge, have knowledge in common, builds a mental bridge between sender and receiver. Interaction plays a critical role in developing ideas. Collaborative interaction can be a catalyst for visions, innovations and learning (Nonaka and Takeuchi 1995, 61). Mutual trust is built in sharing one's original experience. Thus the group members can grasp the world between themselves. A creative understanding occurs. Each member of the group has a part of the truth, a valuable perspective to bring to the process. What the group creates collectively is something that no one of the members could have created alone.

When a group has developed this far, it has become a team that acts in a self–regulated way, in joint responsibility and close collaboration. The team utilizes the differences of the team members and aims at common targets of value and goals, using common rules of action (Katzenbach and Smith 1993, 45). Further on a team is self–regulating in reference to the organization of work processes and the definition of goals. In this sense it differs from other sorts of groups.

Problem based learning as developed by the PLOT members (Dumbrajs 2000; 2001, 21) aimed at including all these features in the learning process of the students. However, it should always be up to each teacher to decide how much of this approach she wants to include in her teaching. One difficulty certainly would be to create self-regulated teams. Students do not normally work together with the same group members over a long period of time. Especially when moving from primary school to secondary school many of the classmates will be new. Thus the possibility of development of a team is endangered. Self-regulated work might become impossible.

The goal of the work in the PLOT project was defined as follows: The members were to develop and test an assortment of laboratory tasks in physics and chemistry that are suitable in the primary school in grades five and six. Children of this age often in their free time build equipment and perform experiments that have relevance for their understanding of physics. Unfortunately it is well known that experiments performed by children alone do not change their conceptions as much as if they have an adult guide (for a review see Matthews 1994, 146). Also, if an adult is not supervising the experimentation, misconceptions can easily arise. The role of the teacher and expert is important. A guide for the primary school teachers should therefore also be written. By carrying out few experimental tasks the students come into contact with many regions of physics and chemistry. They should then under the supervision of the teacher be able to conduct new experiments and find new problems. In this way they are guided forward in their investigative learning.

The data used for the PLOT project was collected from the students' notes and logbooks during the years 2002 and 2003. Also observations made by me and the primary school class teacher during the same period are included. (See TABLE 2.)

First experiences

As a start the PLOT members compiled in their common sessions some experimental tasks in optics. The tasks were tested under the guidance of Moa, the primary school teacher, in grades five and six. The students

were keeping a logbook of their investigations. In the following session Moa reported about her own experiences and together we analyzed the logbooks of the students. We made necessary changes in the assigned tasks and planned the next step. Moa had knowingly refrained from teaching her students facts. They thus needed to make some questions. In order to prevent the students from forming pseudo-understandings and to explore and cautiously correct already developing non-scientific understandings I visited the class and made investigations with the students and discussed with them. In this way it was possible to control the process of learning. Anyhow we thought it was important not to give an answer to all the students' questions. Thus it was possible to keep the interest alive. I also emphasized that in physics and chemistry there are no finite answers, but that science is developing continuously. During the first phase of the work of the team we devoted the main part of the interest to the development of experimental tasks. Later the guide for the class teachers got most of the attention. We thought that it was important to take care of the possibility to achieve fulfillment of the demands of the curriculum within this approach. We defined the aims for each part of the scope, planned the process of instruction, suggested homework and gave the teacher hints about accompanying readings (see Appendix IV).

Report from Vindängen

The students in the sixth grade in Vindängens skola in Espoo together with their teacher, Moa, tested some laboratory tasks in optics that the PLOT team had prepared (see Appendix IV, Optics). Moa reported about the lessons in the following way:

> *I made copies of the papers I got and the students in grade six (22 in number) were allowed to choose those tasks that interested them and perform them together with some peer. Equipment was ready in the classroom. The students used 3-4 hours in January 2002 for laboratory work and reflection. I also took part in the laboratory work. Some students made some notes about their thoughts.*
>
> *The students were eager and showed interest during the whole procedure. We finished with a common session, where everyone could report about*

the tasks they had chosen, what was surprising, what did not work, which phenomena they would like to get deeper involved with, and so on.

……

I am happy that our class was allowed to take part in your project. It is a pity you were not here, when the sixth graders were allowed to start with the laboratory tasks. The eagerness was not to be overlooked. I only hope that I now succeed in guiding the work, when we will try to get a bit deeper into the problems. I told my students that if we are not successful in finding out what we want to know, then we can turn to you for help.

All experiments were not useful. Some tasks we had formulated in such a way that the students had difficulties to understand them. For example terms like *matter, beam of light* and *physical law* we had used without explanation. The students did not choose these tasks. The tasks that concerned what happens, when light hits some matter and what happens, when light is reflected, were most popular.

At the next stage the PLOT members concentrated on the two experiments concerning the refraction of light at the borderline between water and air[17]. In the first experiment the task is to study a pencil that partly is under water. Then one should study the uncertainness and its reason, when one tries to hit a stone in the water with the pencil. In the second experiment among other things total reflexion of light is studied. I analyzed the notes of four pairs of students.

The first laboratory task

The students in four of the groups (A, B, C, and D) made the following notes about the first experiment:

17 1. Take a beaker of water. Put a pencil partly down into the water. Study the pencil from all directions. What do you notice? Put a small stone on the bottom of the beaker. Point with the pencil in the direction of the stone above the water surface. If you bring the pencil into the water in exactly this direction, will you then hit the stone? Can you explain the phenomenon?

2. Take a large container of water. Put a stone into the container. Investigate the stone from all directions. Suddenly the stone disappears. Explain the phenomenon.

A: The pencil becomes bigger if you look from some directions and then it is normal if you look from other directions. Nothing else is happening even if you have a stone in the beaker. The pencil does NOT hit the stone.

B: -When you have put the pencil into the water it looks thicker. – When you have put the stone into the beaker and you try to hit the stone, it goes to the side instead of hitting the stone. Explanation: When you let loose the stone, pressure waves come with the speed of the pencil that are returning from the stone when they have landed (the pressure waves) and against the pencil and then the pencil comes off balance and then it goes skew.

C: It looks thicker. It does not hit the stone, because the pencil looks like it is more to the front than it is.

D: It looks thicker when you put the pencil into water. When you let the pencil fall on the stone, it goes to the side.

All four groups note that the pen looks thicker, when you look at it through the surface of the round beaker. From here students can be guided to investigate lenses and their properties. Group A has observed that the pencil looks normal in respect to its thickness, if you look at it from above. All also agree that the pencil does not hit the stone. Group B has a very complicated explanation for this. Group C gives the commonly accepted scientific explanation for the phenomenon.

The second laboratory task

The results of the second experiment are dependent of the sort of water container the students are using. A low, rather big transparent basin is suitable. Total reflexion appears from about 49 degrees angle of incidence, when the light proceeds from water to the interface with air.

A: When I look at the stone I do <u>not</u> see that the stone disappears. But when I rotate the glass the stone becomes bigger and smaller.

B: .. when you look at an angle from below you do not see the stone because if you see the stone in the water you can't see it and if it is not in the water you see it.

C: It is not seen if you look at an angle from below. Because the water reflects the stone, so it is not visible from all directions.

D: A big part of the stone disappears when you look at an angle from the lower edge.

The notes the students have done are here a bit confused. Group A has observed that the round surface of the container-side works as a magnifier. Again, there is an excellent opportunity to discuss lenses. It seems like group B would have studied the mirror image of the stone on the water surface, when they look at this from below and at a big angle of reflexion. The groups C and D have studied the disappearance of the stone by trying to look at it through the bottom of the container. It seems that group C has a reasonable explanation for the phenomenon even if the concepts are confused.

Students learn how to investigate

None of the groups noticed that the pencil seemed to be broken at the surface of the water. In order to show this and to further point out some other phenomena I visited the class to give a lecture.

I explained the principles for a researcher's work. It is important always to be open for new problems that may appear. It might be a good idea to keep a logbook, where new problems, ideas and reflections are noted. When a problem is solved or has been answered in a satisfactory way a line can be drawn through the corresponding note. In this way it is possible to follow up the progress in learning.

The students were divided in groups of four. The primary school teacher Moa, who knew her students, took responsibility for forming the groups. In this way we achieved groups that functioned well, in which the students were able to collaborate. Each group got three pictures to study. These are shown on the first page of this chapter. The first picture shows a girl, standing in a swimming pool. Her hands reach the water surface. The fingers are in the water. On the second picture a boy in a canoe at the shore is seen. One oar is partly in the water. It is clearly seen that the oar seems to be broken just at the surface of the water. The third picture shows the beams of sunlight in a foggy forest. I asked the students to study the pictures. If they noted some peculiar things, they should make notes of these and then discuss their notes in the groups.

A lively discussion took place. The students went through the individual notes in each group. Some problems seemed to get their solutions already

at this stage. The picture of the girl in the swimming pool caused among others the following questions:

-Why isn't she wearing a life jacket??

-Why does the edge in the background look different than in the basin?

-Why does the girl have orangutan hands?

-How does the water give the girl Donald Duck feet?

-How do the legs get shorter?

The two first questions show how great the students' power of observation is. The three later ones show that pictures concentrating on some physical phenomenon can give directions for further work. This was confirmed by the questions that the students made about the second picture, the one with the oar partly in the water.

- Why you see a bent oar?

- Why the paddle is bent in the water?

- What are the white spots in the picture behind the canoe?

The forest picture did not cause many comments. The students did not find anything especially interesting in this picture.

-What is so special about the forest picture?

-Why are the shadows of some trees at an angle when the sun comes straight against them?

Here I had to ask a helping question. Is it always possible to see the sunbeams? Now the discussion started.

At the next stage the students reported about their reflections and problems by groups. The other groups could then comment and discuss. I did not yet give any explanations to the phenomena. The students themselves answered most of the questions, but some investigations we postponed for future research. These were:

-What does something look like, if you look at it from below the water?

-How does the light move through the water vapour, when you throw water on the stones in "sauna"?

The first question the students were going to investigate at the next visit to the swimming pool.

It is important that some questions and problems remain unsolved. In this way the interest is contained and the research process goes on.

At the end of the lesson I allowed the students to perform the two experiments they had started with once more. Now they discovered without difficulty that the pencil seemed broken at the water surface. Together we drew a picture of the phenomenon and drew the way of the light from the tip of the pencil to the eye. Now the students also understood why the girl on the picture had orangutan hands and short legs. The refraction of light had become a concept for the students. – Problems that had not yet been treated, like for example why the pencil seemed thicker when observed through the side surface of the beaker, and the total reflexion, were written into the logbook.

The expert

Problem based learning with the help of a facilitator or guide and a subject expert is an ideal way of learning. Learning in schools at all levels has become a common interest among experts and researchers. With the help of new techniques expert help is nowadays available for everyone on the web. It is only up to teachers to take the jump into cyberspace.

One of the subject teachers, Vera, tells in her own words about her experiences as an expert:

> *"I have together with two teachers in primary school at grade 6 and their classes tested some of the experiments. First we did optics; reflexion, absorption and scattering of light. Later we did an experiment about density. The pupils wrote down how they performed the experiments and what they observed. In one of the classes every pupil wrote down his/her own reflections and in the other every team wrote their story collaboratively. My opinion is that they reflected about what they did in a deeper way if each pupil had to write his own narrative. Some of them described very thoroughly what they had done and what they saw happening and made conclusions, others wrote down only a few sentences about what they had done. Of course there were some misunderstandings and some unanswered questions. Some weeks*

later I went to the classes as a tutor. We then only dealt with density. I had taken with me some material from the laboratory of the secondary school, for example some cubes of different materials, a bottle containing some mercury and a gas-burner.

One of the classes had written down questions about the phenomena they had studied. Every student had written down a couple of questions. They did not differ very much from each other. After a short while we left the questions and had a free conversation. In the other class the questions were more spontaneous and nobody had written down anything. In both classes the discussion became very free and vivid and we ended up in the sky via the question about smallest possible density. I replaced us into the classroom again by demonstrating some things I had brought with me. We could not answer all the questions and I said that they should bring up the unsolved problems again in the secondary school. One such question was about air and its density. In autumn we shall investigate this problem with the help of a balloon and laboratory scales.

The teachers of the classes enjoyed working in this way and they have critically examined our teachers' guides and thus helped us making them better."

5.3.2 Reflection on team performance[18]

Self–regulated learning is a continuously adjusting process founded on experience lasting the whole life. It contains interaction between the individual and the environment. It is known that effective learning in an organization is achieved if the employees are allowed to solve independently problems related to their own work (see for example Koslowski et al. 1999, 263). The self–regulated individual thinks in an autonomous way and forms her own opinions about things. Self–regulated learning causes positive emotional experiences, wherein one sees one's own situation strengthened in one way or other (Knowles 1975, 9-11, 64). The project of learning is born as an answer to an everyday challenge. The need of development and learning is concrete and limited. When one comprehends the possibility to succeed with the effort-demanding process of learning, one experiences motivation and work-satisfaction.

18 Theory is presented as needed for the plot of the narrative.

Perhaps the most important result of working on the PLOT project was that all members could learn from each other. They noticed a continuous development of their way of thinking. All teachers experienced the collaboration very positively. One of the teachers stated that only because of the teamwork it was endurable to work as a teacher. It was useful to be able to tell about beliefs, experiences, concerns and delights. In the beginning someone got scared looking at the big amount of work to be done. However, the collaborative work and the enthusiasm of the others helped everyone believe that they could achieve the goal. The primary school teacher got instructional guidance and backing from the subject teachers. This interactive relation was labeled by openness, trust and commitment to the common task on both sides.

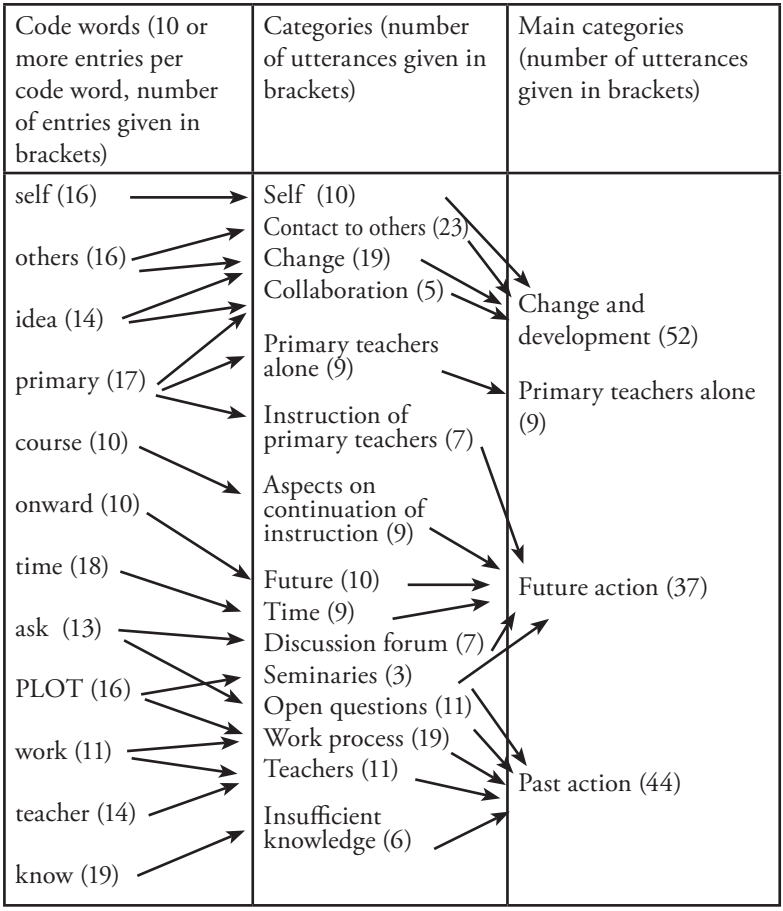
In the team a good collaborative atmosphere dominated, even though the opinions often clashed. While the older teachers emphasized the importance of understanding in the learning process, a younger subject teacher, Lena, stressed the importance of connecting physics and chemistry to everyday experiences and the class teacher, Lotta, wanted to make the students think in an independent way and to get them to investigate different issues with an open mind. On top of this she wanted to give the students knowledge about facts. The more experienced subject teachers stressed problem solving and collaborative work in groups as teaching methods, but Vera pointed out that there are also students, who prefer to learn by other means, for example by reading and writing. Lotta was of the opinion that students learn by doing. – The above results were extracted from the answers to the questionnaire in Appendix I, which the PLOT members delivered in the early autumn 2002, having worked together for around half a year.

The team thus formed a rather heterogeneous group also according to teaching purposes. Problem based learning in the form where self–regulated learning, working in groups or teams and problem solution are emphasized was not familiar to the younger teachers. They had no concrete experience of this teaching method, though Lotta was acquainted with the method from her studies.

At the time, when the end of the project became visible, i.e. summer 2004, all the members of the team were interviewed. The question to be

answered was: What have you as a teacher and as a human being gained from being a member of the PLOT-team? Depending on how fluently the interviewee could express herself and how clear she was about her opinions I intervened with comments and suggestions, but I always tried to follow the strain of thought of the interviewee. The interviews were transcribed and the interviewees were given opportunity to comment on and correct the content so that it agreed with their original intentions.

TABLE 4. Categorization of interview data. Teachers in the PLOT team were asked to describe how their development as teachers and as human beings changed their professional life as teachers. The arrows indicate the regrouping during the categorization. A more precise account is given in the text.



The intention was to find changes and developments in the teachers both concerning their way of teaching and their personal opinions. The program QDA Miner was used for statistics and frequency of words appearing in the text and labeling and selecting of utterances. The code words that I found relevant are presented in TABLE 4. There was one code word with 35 entries, "can", that I did not take into account. I however thoroughly checked the corresponding utterances for relevance. In most of them "can" was used as a modal verb, a few could be replaced under the code word "know" and in the remaining cases the utterance contained an additional, more relevant code word. This was also true for most of the code words that received less than 10 entries. Utterances were labeled according to their code words. The same utterance could appear under more than one label. The utterances in the separate groups were investigated with regard to structure. In some groups the utterances could clearly be divided into subgroups. Some groups and subgroups contained utterances closely connected to each other. These I combined into the same category. In TABLE 4 the arrows indicate the rearrangements.[19] For example the group with code word "others" contributes to the categories "Contact to others" and "Change", while

19 To make an example we take three utterances that contain the code word "primary":

A. But it could maybe have been two teachers, one primary teacher and one secondary … a subject teacher, that would have worked together. (Vera)

B. The danger is that primary teachers teach so many subjects that they have difficulties to find time. (Michaela)

C. I will see in which form it will be, but so that … so that all primary teachers that teach grades 5 and 6 next year already in the autumn would get at least one afternoo … that is one further … half a day of further training. (Vera)

They go into three different categories:

A – "Collaboration"
B – "Primary teachers alone"
C - "Instruction of primary teachers"

and into the main categories:

A – "Change and development"
B – "Primary teachers alone"
C – "Future action"

Please, note that the pseudonyms attached to the utterances have been added after the analysis was ended and the results written down.

both groups "PLOT" and "work" contribute to category "Work process". Of the 15 categories that I achieved it was possible to group 13 into main categories. One category, "Seminaries", contained aspects both on the past and future and accordingly was divided between these two main categories. Only the category "Primary teachers alone" with 9 entries could not easily be included into any of the main categories. Please note that the number of entries in the main categories does not equal the sum of entries in the lower level categories because some utterances appear in more than one lower level category.

- Change and development [52]
- Past action [44]
- Future action [37]
- Primary teachers alone [9]

The content of the above four categories tell an intriguing story about the teachers in the PLOT team. In the following I will describe their worries and pleasures, their abilities and failures and their development as teachers, all with the help of their own utterances in the interviews that formed the ground for the above analysis.

Reflection on changes and development of attitudes and teaching

Often the teachers feel lonesome in their daily work and the contacts with colleagues are superficial and influenced by stress and a tough timetable. The contact within the PLOT team was thus considered as valuable. The teachers especially valued the possibility to exchange thoughts with each other. To be allowed to discuss common problems with others who know what the essential question is about and understand the situation might open new perspectives and create new thoughts.

> *- I find that I have become a part of a community and got a confirmation that the thoughts I have had and tried to realize are right. Where I often felt rather alone in my work. We try to realize the same thoughts and ideas that I started to develop many, many years ago. .... I experience that I can rely on PLOT and feel secure together with the team members. (Michaela)*[20]

20 Please, note that the pseudonyms attached to the utterances have been added after

The teachers enjoyed the company of each other and felt secure together. This could also be noticed in their daily work. They visited each other's lectures, they worked with open doors and they shared knowledge, and sometimes students, between each other, all this to a much higher degree than earlier.

> *- But as teacher I am like .... to work in the PLOT team has been fun. Funny and interesting questions are discussed, as we many times have noticed, and we start to think about rather curious things. And this is precious. (Lena)*

The PLOT members themselves noticed that they started to find new and interesting phenomena in physics and chemistry due to their reflections on the subject and on how to present phenomena to their students and the primary school teachers.

> *- … I can, being out for a walk, start wondering about something, some chemical thing, like … (Lotta)*

There is an experiment, where you put a candle to stand in water, light it, and put a glass upside down over it. When there is no oxygen left under the glass, the candle goes out. The water surface in the glass rises and takes up one fifth of the volume. From this it is concluded that one fifth of the air volume is oxygen. - Learning from their students how to be interrogative the teachers asked themselves the question: "But where does the carbon dioxide go?" As much of this gas should be produced as the amount of oxygen that disappears. Until now they have not been able to find an answer. But it is clear to them that life is not as simple as often assumed.

Also to experience things together is seen as valuable. Be it then keeping work shops for primary school teachers, presenting results at some conference or just traveling somewhere to take part in a project.

> *- Because if you experience something together this is something ... it is a seed and it will grow of itself, when you have been more than one. (Michaela)*

The teachers in the PLOT team came into contact with teaching according to the PBL method in two different aspects. First, as members of PLOT, they had the task to convey to the primary school teachers the teaching

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the analysis was ended and the results written down.

philosophy of their team. This happened during the workshops that they kept for primary school teachers (subsection 5.4.2). Secondly, they themselves learned the strategies they recommend by practicing them in their own teaching. Few of them had used problem based learning to a greater extent in their teaching before joining the PLOT project. Thus they had to rethink their own roles as teachers.

> *- Well, it has influenced me, maybe, in the sense that if I had not had this PLOT background, I might have given too many answers. I would have answered too many questions. Now, thanks to this PLOT background and this idea, which PLOT has, that one should not … that one may not answer … well, that the student should not get too many answers, this has maybe influenced me in the way that I keep back … (Lotta)*

Some members took part in seminars and further training organized by the National Board of Education and by the University of Helsinki in order both to develop their own understanding and to sell the PLOT idea.

> *- No one stressed this with open questions. Working in groups was quite clear and they should work just in this way … this all lecturers mentioned. But … it was never commented on that … that one does not need to answer all questions … (Lena)*
>
> *- But I myself think that often one has to admit that this I do not know … (Lena)*
>
> *- And slowly one starts oneself … to get one's own thoughts and ideas and it becomes closer to reality …(Lena)*
>
> *- But still I am … rather insecure, when I do such … open-ended laboratory tasks. I think that it is because I do not have much experience. (Lena)*

All PLOT members tried to take the students more into account in their teaching. They thought about and planned their lessons in a more conscious way. The dialogue with students and among students became one of the main learning strategies.

> *- I have, how to say, I have taken the students more into consideration now. And I do believe that the students are of the same opinion. One thinks about what one … one plans the lessons in a different way. (Vera)*

One aim became to show the students the way to develop into analytical and critical human beings, who are able to reflect and think about things themselves.

Past action

The laboratory tasks and teacher's guides have been ready and in use for more than three years. They are available on the web site of the National Board of Education. Thus the primary school teachers have possibility to learn to know the material. The PLOT team members had developed their own homepage, where besides the published material also a discussion forum was available. This existed until the autumn of 2005. In the interviews from summer 2004 the PLOT teachers expressed their thoughts about the results achieved so far.

The teachers' guides and the workshops were seen as finished projects. The work on the PLOT pages had been agreeable.

> *- and then … the … the PLOT pages themselves; it has been fun to work on them, but it has also been disappointing … this reception … (Vera)*

The work shops were appropriate from the point of view of the PLOT teachers.

> *- I liked the work shops…(Vera)*

It was a disappointment that the interest from the side of the primary schools was limited. The PLOT members felt that they had not been able to sell their products in an efficient way. They had also hoped for more help from the National Board of Education in this respect.

> *- ... as this reception of the laboratory tasks and teachers' guides has been a bit ... so and so ... Is it so that we in small Swedish speaking Finland all are working in our own corners? Is ... these publishers of school books are trying to do their books for grades five and six ... and we are doing this for grades five and six and [*the pedagogic faculty of Åbo Academy*] surely is doing something else for five and six and no one ... no one is coordinating it. (Vera)*

The responsibility for the slow development of the process of taking the material into use was weighing heavily on the shoulders of the PLOT members.

- So it has been a lot of work and little performance .. (Vera)

They felt that they did not finish this part of the work quickly enough. The members had a very critical approach to their work, but the biggest fault they found in their incompetence to sell their product.

… it is so that we have not been able to make the public relations, which would have been necessary … (Vera)

At the moment, however, all schools have taken the new curriculum into use. The PLOT teachers hope that their efforts were not in vain.

- But on the other hand I do believe that our work was expedient. (Lena)

Primary school teachers on their own

The team members could well understand the situation in which the primary school teachers were. It was, however, assumed that these would have more experience of problem based learning than the subject teachers in general, because of their more thorough pedagogic education.

A question that the team has lived with since the beginning is how to bridge the gap between primary school teachers and subject teachers.

- There is ... there is an invisible wall between us and them. And I do not understand why. (Lena)

It is very important that one of the PLOT members was a primary school teacher. This fact signaled that all teachers together were working for the same goal.

The logbook that the students are supposed to keep and that should follow them from grade five the whole way to secondary school would help to make the learning into a continuous process and the subject teacher would have a clear picture of what the students have learnt in primary school.

- If the primary school teachers are insecure that are they doing "right" ... have the students written their log in the right way. It has to be made clear that it is not necessary to do it in some special way, but ... (Lena)

The teachers' guides in combination with the books that were to appear were assumed to supply the tools that the primary school teachers would need. A discussion forum (see subsection 5.4.2) was seen as a supplement. The plans for such a forum on the web were greeted in a very positive way. The PLOT members were, however, scared that it would involve a tremendous amount of work to answer the questions that the primary school teachers and students would make. They hoped

- ... that it will survive and flourish of itself when thoughts and ideas have "got ground under the feet" in many schools. (Michaela)

Reflection on future action

We devoted much time to think about the workshops and the possibility to close the gap between primary and secondary school. Would it be possible to convince the primary school teachers of the importance of keeping a logbook or a portfolio? Another problem that got much consideration was how to make the PLOT material known among primary school teachers. The only possibility seemed to be spreading knowledge about it at seminars and further education for primary school teachers.

Already in 2003 the PLOT team organized a seminar for primary and secondary school teachers, and for researchers in education from the universities of Helsinki and Joensuu and Tallin Pedagogical University. The seminar was positively appraised. In 2005 the next seminar, this time in collaboration with the Tekniska Föreningen i Finland (Technical Society in Finland) and the National Board of Education took place and in February 2007 the series of seminars continued.

- It … it … But on the other hand we have this seminar which also is a PLOT result. It feels good. (Rolf)

The discussion forum never worked as expected. The primary school teachers have never started to use it. Here the subject teachers too would encounter the problem of time.

- Because, if something should be answered in print, one has to verify one's own opinions and knowledge so that the words certainly will be appropriate, however skilful one is. (Michaela)

Another problem of time, which the primary school teachers will meet, is the need to go through the available material. They have to teach so many subjects that it will be difficult to find time to enter deeply into physics and chemistry.

Conclusions

The PLOT members wanted to develop the PLOT principles in their own schools. They hoped in this way to find those enthusiasts that might spread the PLOT material to other schools.

- So that I would like, show them this program and then we would go through some … only show … just these materials … find out which materials one needs … (Vera)

- I will consider in which form it will be, but so that … so that all primary school teachers who have fifth or sixth graders next year already in the autumn would get at least one afternoon … that is one continuation training … a half continuation training day. (Vera)

They had learned another way of instruction and they had become confident that this method not only gave good results but also made teaching more appealing and interesting.

All teachers thought that they had gained something from working in the team. All, except, for obvious reason, the retired teacher, Michaela, had changed or tried to change their methods of instruction in a more dialectical and interactive direction. This they had achieved through reflective discussions with each other and through self-reflection. Not only to learn from each other and in conversation with each other, but also to be approved and accepted in a communion of equals was of utmost importance. In the team there was time to talk and reflect. One could notice a certain reluctance to break up after the meetings. As one teacher mentioned "… they are perhaps not so effective these evenings, just as today, but … still we are sitting here one hour and no one is in any sort of hurry to leave". This feature was at least partly due to the fact

that the meetings were held late in the evenings, not directly after the regular school day.

5.4 An experiential learning environment

The intention was that, with the help of the PLOT material, the primary school teachers would be able to create an innovative learning environment for their students. At the time being there are experiments and teacher's guides concerning the properties of light, mechanics, electricity, acoustics and heat, and density and chemistry available (Appendix IV). Working with the material should encourage teachers and students to apply the knowledge they already have in solving problems. At its core is the release of the students' natural creativity and imagination. Rather than teaching the answers it encourages a relationship between teacher and student that moves the students towards the discovery of their own practical solutions to real problems. Students learn to look carefully and critically at the material world that surrounds them and develop critical systems thinking and practical skills.

5.4.1 To learn how to innovate

To learn means to find a way to be able to act in agreement with the essentialities we meet in life. To teach is more difficult than to learn because teaching demands that the student is allowed to learn. (Heidegger 1954, 8, 15) The liberal, humanistic education values freedom and development of the inner capacities of the student. The education should not only comply with the ongoing demands of the society, but also be seen in a wider perspective of time. Students should be guided to understand the complexity of the systems in which they live. A non-instrumental picture of education aiming at inner norms instead of outer ones should be predominant. In his discussion of Heidegger's views of education Cooper (2002, 51) emphasizes that the student should be given the possibility to form her own opinion and experience of what truth means. The content of education should be based on the essence of

truth. Education should be understood as an initiation to what it means to be a human being (Allen and Axiotis 2002, 35)

The teacher should perpetually and carefully pay attention to signs showing the direction of the student's thoughts. It is a question of divining what is not yet said, perhaps even not thought. This is based on a genuine, authentic listening. The process of thinking of the student should be allowed to develop freely, without considering curricula and division of knowledge in subject categories (Allen and Axiotis 2002, 41). The student should be allowed to integrate between different instructional subjects. In this way several aspects of the systemic life world can be recognized. The teacher then never has a firm ground under her feet; as such processes cannot be defined beforehand. A genuinely creative, open atmosphere between teacher and student is decisive. The teacher tries to guess the qualities of the student's current cogitations and help her feel for herself what is important to consider in this connection.

Similarities between systemic patterns should be made visible in order to connect real life problems to teaching in the class. Lately the importance of authentic teaching has been stressed in the curricula for our schools. When a student learns by taking part in a process aiming to solve a problem in real life or to create useful products for real life, she is learning in an authentic way. An authentic occupation is purposeful, because it has to do with questions, asked in real life. The student does not learn only in order to know something, but primarily in order to reach a goal. But is there not always a public understanding present distorting the student's unique and authentic perspective? How large is the authentic part of the education, how much is everyday information and commonly accepted principles? Does the student have a possibility to herself carefully interpret and assess what she is supposed to learn, using her own considerations about her own existence and the valid conditions of her own life? It is important that the student has the possibility to search and is encouraged and assisted in her searching. She herself must decide how she should value the achieved knowledge. How should it influence her attitudes and actions?

Preparing children for life is an enormous responsibility. Teachers and parents engaged in this process do their best to prepare the students for coping with the world and for being able to make contributions to the future development. They thereby also influence the development of the student's personality and her ability to balance conflicting factors. Coping with the world includes, besides having necessary skills, knowing what the physical world and society have to offer and what is attainable. It also means that the student is familiar with the rules valid inside her cultural horizon and conforms to them. In the preparation of humanhood both learning to respect and enjoy the realizations of humanity as well as seeing the negative features is considered. Last but not least the student should be able to enjoy the beauty of nature. Developing the student's personality means, among other things, that she learns to identify and enjoy her individual capabilities and strengths, thereby finding her own role in society. In this role she should see her responsibility for other people and enjoy helping them. (De Wolf 2003, 98-103)

Authentic learning in a group

I myself was not in a position to teach in a fifth or sixth grade. I did also not get permission to audio tape lessons in primary school. However, I used the same principles of PBL in my instruction as the ones we introduced to primary school teachers. In the following I present a sequence from physics lessons in secondary school as an example of how a learning situation might develop and how a teacher can guide it. With the permission of the concerned parents I audio taped the lessons and transcribed them (see Dumbrajs 2001, 28).

A group of students considered the concept "velocity" with the help of me (Sibban) as tutor. They could also consult an expert, the subject teacher Thure from the upper secondary school, who was at their disposal for discussions. After some difficulties in getting started the students found an interesting, for the tutor unexpected aspect on the problem of "velocity".

The tennis player Lasse put forward an initiative of his own:

Lasse: Isn't it also if you hit a screw ball?

The tutor encouraged and Lasse and Hans started a lively discussion.

Sibban: How does it affect this screw? How does it affect the velocity, when you hit a screw?

Lasse (showing): How? Then the ball stays … the … if you had an overscrew the ball comes … how does the ball come?(thinking) … Äää …

Hans: It pops down!

Lasse: It pops down … like this (shows).

(mumble)

Sibban: Huh!

(mumble)

Hans: … If you hit an under-screw, then …

Lasse: … then it is floating in the air .. and is hovering like ..

Sibban: What is it that makes, well, when you hit a screw, then… What is it that does … well, the ball is round, isn't it, and what does it matter how it …

Lasse: It is that … racket …

Hans: How you hit …

Sibban: Yes, well, it has to be that it rotates somehow, when you hit a screw… It rotates … Yes.

Hans: It depends on the material with which you hit..

Sibban: Does it depend on that also?

Lasse: Yees… If you have loose strings or hard strings …

…….

Sibban: Uhuh… it becomes … it becomes complicated. Now I do not know at all, let's hope that Thure knows about it …

Lasse: If you hit from …

Hans: When you serve, you hit from the side …

Sibban: Hallo, I think those (other groups) start to discuss … Do we have enough?

The screw of the tennis ball was a quite new theme that, however, was clearly connected to the concept of velocity. As this had awoken the interest of the group, the tutor decided that Thure should explain the connected concepts. There was no explanation in the students' physics

books as the phenomenon of rotation was part of the curriculum for the upper secondary school.

Thure connected to the gravitation force, which is a concept the students knew. He told about the potential energy, which an object on an inclined plane has. The object has potential to do work because of the gravitation force. When the object moves down the inclined plane, the gravitation force performs work. The object looses its potential energy and gets kinetic energy. The sum of the two energies is constant. An object that can rotate has two sorts of kinetic energy, rotation energy, which causes the rotation around its axis, and translation energy, which takes the object forward. Thure took the curve of death that motor bike drivers perform in the circus as an example for kinetic energy. The driver has enough translation energy to stay in orbit. A ball can perform the same movement in a circular orbit (Figure 6). If it then also rotates, its starting point must be higher up, which means that its potential energy is bigger; otherwise it does not stay in the orbit. The earth is moving in an orbit around the sun and at the same time rotates around its own axis. The tennis ball is also doing this when it has got a screw; that is it rotates around its own axis and simultaneously moves forward. But the total energy in the system is constant.

The students were listening attentively. When Thure had left Lasse was still sitting there carefully copying everything from the blackboard. It seemed that an understanding of the concepts rotation and energy was developing. His interest was at top, because this was Lasse's own problem, his tennis ball. He owned his learning. This was possible because he learned in an authentic way starting from his own prior knowledge.

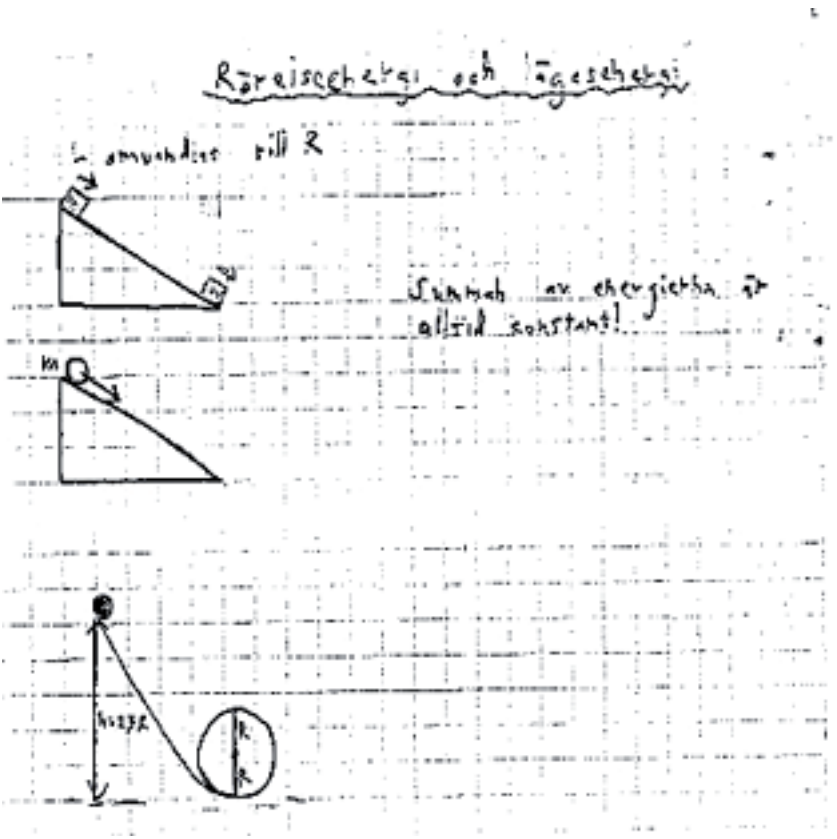

Figure 6. Lasse's notes from Thure's lecture about rotation and energy.

Students should only be given guidelines for how to approach problems

Most young students are curious, they want to know. However, an impatient, stressed teacher brushing aside their questions takes the joy out of their inquiry. Nothing can justify killing a child's curiosity through a causal remark, look, action or inaction with the excuse that the question is irrelevant for the present problem, or that it will be considered later according to the curriculum, or that there is no time for answering the question at this moment. It is quite a different thing to

show appreciation for the aspect of consideration the student suggests, but leave the question unanswered in the expectation that the student herself later will find the answer.

In the spring term 2003 some young students in grade 6 of Vindängen's primary school investigated how heat affects a metal ball with the help of their teacher, Lotta. They made notes of their observations and thoughts. Their equipment consisted of a plate with a circular hole the diameter of which was such that a metal ball just could pass through the hole at room temperature. The teacher beforehand asked the following questions:

1. *What will happen to the metal ball when it is heated?*
2. *Why?*
3. *What will happen to the ball when it is cooled down again?*

No other introduction to the experiment was given.

The teacher heated the ball. Consequently it could then not pass through the hole, but got stuck. After the ball was cooled down it passed through the hole. The students wrote down their thoughts about the experiment.

> *Student 1: The ball passed through when it was cold. Then it was heated and became bigger and did not pass anymore. I think that the ball widened, when it got hot. When it was cooled with cold water, it started to smoke because the cold water evaporated when it hit the warm surface. When the ball was cold again it passed. The ball changed color, when it got hot. – Why did the ball widen, when it got hot?*
>
> *Student 2: How much does it weigh? Does it have the same weight when it is cold?*[21] *How can it cool down so quickly, if it is metal also inside, because it must also become hot inside?*

It is interesting to note that the children have lots of questions. Of course, to some degree the students repeat the questions taken up by the teacher. However, they give experimental answers to some of the questions. But they also find new problems, like the weight of the ball under different

21 Inquiry learning has been strongly criticized for its inductive approach (e.g. Matthews 1994, 147). However, here we notice the use of allowing young students to speculate. The subject teacher can later ground the instruction on those problems that are important for the students to understand (see Dumbrajs 2006).

conditions and the ability to conduct heat in metals. This is not the case if the teacher starts by explaining the theory of what happens. Then the students note only the features that have been discussed.

Reliance on problems to drive the curriculum

It is not certain that the teacher would have discussed the weight of the ball when giving the students the theoretical background of the experiment. For the young students this problem was, however, of utmost importance in trying to understand what happened. In problem based learning the students discussed the problems from their introductory brain storming in small groups around half a year after the original experience, already having reached grade 7. With permission from the students' parents I audio taped and transcribed the discussions of the students.

> *Student 1: "What is the weight of the metal ball?"*
>
> *Student 4: "Is the weight the same, when it is hot as when it is cold?" "How can it cool down so quickly, if it is metal also inside, because it must also become hot inside?"*
>
> *Student 2: Well… It would have to have the same weight.*
>
> *Student 1: Yes, the weight is the same.*
>
> *Student 3: The molecules[22] need more place… They do not have more weight…*
>
> *Student 1: Well, they haven't.*
>
> *Student 4: Is it so that the molecules… when they like cool down faster…?*
>
> *Student 3: Yes, it could be…*
>
> *Student 4: Well ….*

It was not quite clear to the students what molecules are, but they obviously believed that they are some kind of constituents of the material. Of course, at this stage of their studies, they were not able to distinguish between atoms and molecules. Here the teacher could, with a simple question, guide the students to think about molecules and what they consist of. Along this path it might also be possible to find the explanation to the problem why some materials conduct heat better than

22 Pure metals consist of atoms. The students use the wrong concept.

others. However, the problem can also be left open until the students have acquired more background information. It should then be written down in the logbook for unsolved problems.

It is not difficult to cover most aspects of the curriculum by just allowing the students to solve their own problems. The different pieces do not always appear in the same order as planned by those who have developed the curriculum, as they were not in a need to find answers to obvious questions. It can occur that the sixth graders, when confronted with an electric battery and the task to cause a lamp to light up, ask themselves how the battery can make this possible. They will then get involved in electrochemistry. Here the teacher must recognize the limits of the students' present knowledge. Do they have the premises to solve this problem? Maybe the present place of the problem should be in the logbook for future investigations.

Students solve the problems

The metal ball and the plate with the hole discussed in the experiment above were made of different materials. When the students in grade 7 discussed their experiences from grade 6, they were also allowed to perform the experiments themselves. Their discussions were audio taped. - They noticed that if they tried to push the ball through the hole once more the ball got stuck again, without being heated in between.

Student 1: "What happens with the ball, when it cools down?" - It widens again…

Student 3: It becomes smaller!

Student 4: It should pass through….

Student 1: It… it..

Student 2: Yes, but it is the ball – it does not become small… Because it is the plate…

Student 3: I see ….

Student 2: Because it is that plate…

Student 3: Yes, yes…

Student 1: That hole…

Student 2: Precisely!

Student 3: Well, nothing happens.

Student 4: You do it once more…

Student 3: Yes, it does not pass the hole any more!

Student 2: Yes, you have to let it go again and again…

Student 3: You put it on the hole again.

Student 2: Hmm… Ok.

Here the students learnt that different metals have different heat expansion features. The plate showed a bigger rate of expansion and contraction than the ball. The students succeeded to solve the problem with the ball falling through the hole again and again (see Figure 7). They were now motivated to look up heat expansion coefficients from their schoolbooks and to discuss the material of the plate and the ball. The eagerness to share knowledge between themselves is clearly noted.

Figure 7. Students heat the metal ball and try to let it pass the hole in the plate. It gets stuck. After some time it falls through. When they try to let the ball pass once more (without heating it) it gets stuck again. Why?

The problems are ill-structured

The students themselves formulated their problems starting from the experimental equipment and the teacher's questions. From the simple experiment with the metal ball and the plate with a hole they ended up with investigating a) which materials can be mixed and nevertheless withstand big temperature fluctuations, b) how are the molecules built, c) what is energy and d) why does the color change with temperature and what is color?

In order to keep the curriculum under control each group in the class reported the results to the other students in common sessions. The students then had many questions to ask. They learned more from their classmates than they would have learned from their teacher. Sometimes the presenting group showed experimentally what results they had got. During the discussion new problems that needed to be solved arose.

Assessment of knowledge, competencies and skills

Assessment is a part of the problem solving process. When presenting the results for the classmates and answering their questions each group member realized to which degree the group had succeeded to solve the problem. Important was that the students understood that there are no finite solutions to science problems. Science develops all the time (McGomas, Clough, and Almazroa 1998). It also became clear for the individual members that only as a group they could achieve a good performance. Their team competencies grew all the time.

In the class that went on to learn according to PBL methods in secondary school two groups were the same for three school years. A change in one group I undertook during the third year. I then tried to resolve a deep conflict that had developed. Two brilliant students, girls, did not want to share their knowledge with their not so brilliant mates any longer. They thought that their notes might become better if they worked in a group for themselves. However, the most brilliant student of the class, a boy, went on to work in his group. He was something of an outsider in the class, but worked well in the group and had nothing against sharing

his knowledge. I think for him the group meant much. It gave him a social environment where he could feel secure and develop his social competence. In a third group there was a boy with potential difficulties in learning and in social competence. These difficulties never got a chance to become real in the environment of his group. He showed great interest in the work and he never misbehaved against his group members.

Individual tests were organized in order to see how well the students had learned definitions, quantities and units. Real examinations always concerned the whole group. I individualized the performances by using tape recorders to record the discussions in the groups. Besides the level of knowledge the discussions showed how the social competence of the group developed. In this way it was also possible to properly take into account students with difficulties to read and write.

Discussion and conclusion

According to Gardner (1983, 60) the human intelligence has three components, namely a) a supply of skills, which make it possible for an individual to solve authentic problems, b) capacity to create usable products or to offer services valuable for the culture in which one lives, and, c) potentiality to discover problems or to make inquires that give the individual possibilities to obtain new knowledge. Gardner names seven different forms of intelligence that are represented in the structure of the brain. Intelligence is mostly connected to logic and skill to make abstractions. These qualities have also been seen as characterizing a good mathematician. But human mental activities are not limited to logical–mathematical operations. Music and dance, poetry, architecture and other arts have to be described in quite different terms than logical lines of thought. And who would be able to say that they do not demand as much training and pedagogical involvement to be able to develop? Gardner's theory about the multiple intelligences is of essential importance for teachers who are looking for new, different learning and teaching methods which would develop a deep understanding by using the student's special structure of intelligence. Gardner is of the opinion that each such structure can offer unique capacities to solve problems.

Thus there is a variation in the understanding of individuals (Marton and Booth 1997, 178). Naturally, the content dimension of learning is of importance. Learning is something that the students understand, apprehend, construct knowledge and deliberate meaning about. The cognitive structures that the individual creates are instruments to be used in order to handle and organize the flow of experiences. Viable structures suit the world of the student, but can never be transferred to an objective reality. Students learn and form their own structures all their lives, also prior to attending school. Their prior knowledge might have been useful in the past. Teaching should always take this prior knowledge as a starting point. If the pre-understanding has been useful, it will demand very convincing new understanding to change the student's knowledge structure. Only if the new understanding can explain all features that the pre-understanding could explain and also explain new problems it might become an integrated part of the knowledge structure. A reflective communication with peers supports this process.

When teaching takes place according to a fixed curriculum and assessing takes place according to standardized criteria, individual students and teachers are lost out of sight. The authentic inner life is destroyed. A blind transparency arises from the calculating way of thinking. What has just been learned soon disappears in forgetfulness, hidden under new knowledge. On the other hand, trust between student and teacher will preserve the integrity of the student. The existence of such an honest connection and the way in which it is integrated in human life forms an essential difference in what the individual sees and feels. The teacher should allow the student to learn. The student has to surrender to both the call to and effort to think.

5.4.2 Spreading like rings on the water

The PLOT project got the support of the school administration in Espoo and on the suggestion of the director of education primary school teachers participated in workshops organized by the PLOT team during the school year 2003-2004. The teaching units, which were also available on the web, formed the base.

We saw it as positive that the teachers' training is directly focused on particular lessons. The possibilities for development on the school level were considered to be greater than if the teachers are sent to attend lectures for further training. The teachers could also be in charge of their own training, which increased their motivation for the task. London and Mone (1999, 119-153) have noticed similar features. However, a negative consequence was that many stopped attending the workshops after some time, as there was no obligation to participate.

The first workshop took place in Mattliden on the 3rd of September 2003. This time ten primary school teachers participated. The participants, altogether 14 teachers, filled in a questionnaire before and after their first workshop (see Appendix II). From the team two or three subject teachers and one primary school teacher were running the workshops. The participants in general were interested in physics and chemistry. This conclusion could be made from the fact that almost all had studied more than the obligatory amount of these subjects in upper secondary school. However, they had on average only little experience of teaching physics and chemistry. All had used problem based learning and/or investigative learning as teaching methods to some extent, but only a few used these methods often. (See Appendix III)

All primary school teachers were of the opinion that their students would react to the laboratory tasks in a positive way. They would be curious and interested and they would have lots of questions. The teachers also thought that the tasks were concrete, simple and fun and would increase the motivation of the teachers to teach physics. Some teachers would have liked to get the "right answers" to the experiments.

The teachers' guide still contained concepts that were unfamiliar to primary school teachers. These should be explained. When using the tasks themselves together with their students the teachers thought that they would be able to comment more appropriately on the tasks. They found the guide useful for preparing the experiments and for further thinking. It was seen as positive that the guide was available on the web. However, one teacher said that she did not use computers at all. Most teachers thought it natural to let the students work and themselves

function as tutors. The only problem seemed to be at which age it would be possible to give the students responsibility for their own work. Certainly the teacher should test the experiments beforehand and the parents should be informed that their children start doing laboratory tasks.

Workshop with a group of primary school teachers

In the workshops the primary school teachers got acquainted with the laboratory tasks under the guidance of a PLOT member. They formed groups of two or three teachers and performed the tasks. In the following we accompany one group by performing the experiment with the metal ball and the plate with a hole, which students discussed and performed in the previous section. The teachers were audio taped during their work.

Lotta: Before starting one can ask the students what they think will happen. Perhaps one should not yet ask why, but later, when they see the result they can think about why. ……..

Teacher 1: It conducts heat so well, so it should be no problem. – Will not the plate get heated, too?

……..

Lotta: That plate is part of what they notice. In secondary school …

Teacher 2: … just .. two centimeters … I would keep that ball two centimeters higher, like that. Because then …

Teacher 1: Then it is hottest..

Teacher 3: Like this? Of course, there the flame comes together. Now. Precisely.

Teacher 1: Now it gets stuck.

…….

Lotta: Wait a bit. What will happen now?

Teacher 1: It will fall in the water when it becomes smaller

Teacher 2: It is so hot that it melts that hole. The hole gets bigger and the ball is falling down. This is my hypothesis.

Teacher 3: Well, this .. the hole that gets larger ..

Teacher 2: The hole gets larger.

Teacher 3: Because the heat is so close to the hole, yes.

Teacher 2: Yes. I am completely convinced.

Teacher 1: … cools down …

Teacher 2: I am completely convinced that this is how it is.

Lotta .. (inaudible)..

Teacher 1: Yes, it is also hot.

Teacher 3: This heating process has to be quicker, meaning that this ball is heated quicker than it is cooled down. In time … You know, before it gets as cold as it was in the beginning, more time will pass from the instance when it is hot ..

……. (the ball is falling) …

Teacher 1: Aaa .. it was so quick!

Teacher 2: It gave the heat to this metal plate. It was some …

When the thoughts of the primary school teachers are compared to the thoughts of the students, one notices a less vivid imagination but also a similar lack of awareness of physical phenomena. Here primary school teachers do not understand the behavior of different forms of the same material. They do not understand what happens when metal is melting or know at what temperatures this might appear. On the other hand they understand immediately that something also happens to the metal plate. Heat conduction is familiar. To a very large degree their knowledge is everyday knowledge and they have many misunderstandings. The problem to understand the rapidity of the cooling process seems to be the same as for the students.

Some of the usual misunderstandings among students are the same or similar among primary school teachers. In the first example below a student in grade six was thinking about why a metal ball becomes bigger when heated and in the second a primary school teacher wondered about what happens when ice is melting.

Student: I want to know why the ball became bigger … I think gas came in and it became bigger.

Primary school teacher: The air in the material disappears by heating and the volume of the material diminishes.

During the work shops the primary school teachers expressed their worry about not always being able to give their students facts. However,

it was stressed that the danger, when answering questions in a definite way, to reinforce students' misunderstandings, is very real. This is in accordance to the study of Rice (2005). She has shown that the subject matter knowledge in elementary school is weak and that teachers have as many erroneous or alternative conceptions as their students.

The primary school teachers did not feel confident about their subject knowledge and also felt that they lacked the time to explore a wide range of materials. Generally, they did not want to seek help. They preferred ready units that worked. They thought that subject content should be expressed in terms that easily can be conveyed to their students. Therefore they were not interested in learning and implementing new teaching strategies. They asked themselves if time is used in an effective way if they allow their students to pursue their own investigations, if the activities should not be teacher-controlled so that the students get the "correct" results, and if students really can learn in a self-directed way. Similar experiences have been quoted by Geelan (1998) from implementation of innovative teaching approaches in a mixed community of primary and secondary school teachers. Beliefs, values and goals that describe the teachers' orientation are at odds with those supporting problem based learning (Volkmann, Abell, and Zgagacz 2005, see also Rice 2005).

The discussion forum

From the answers of the questionnaire and from the experiences of the workshops the PLOT members realized how important the tutorship would be when the primary school teachers started to use the laboratory tasks in their own classes. Not only would they get comments on how to improve the laboratory tasks but also, and primarily, they would be needed as support and motivation for the primary school teachers.

Contacts with other teachers and discussions about some phenomena would make the life as a teacher more interesting. A shared knowledge among the teachers that met on the web would be constructed. Conversations of inquiry and explorations could create learning opportunities similar to those in teams. Especially, in comparison with face-to-face conversation, there would be an increased opportunity for

reflection, as an immediate answer would not be expected. There would be no need to consider time limits. The forum would be open around the clock on all weekdays. And the web would offer increased chances to find people with similar experiences and problems. (Baker 2002c, 172)

Therefore the next step in the work was to open a discussion forum on the web where all, both subject teachers and primary school teachers, could meet as peers to discuss experiences. As questions were answered an archive would be built from which everyone could benefit. Over time a Frequently Asked Questions department would develop from common questions that had arisen. To become a member one would have to register as a user of the forum. The discussion forum was in use only one year before it was abandoned in the autumn of 2005 because of very sparse use.

A typical question from a teacher that had started with the electricity experiments could be:

> *Lena: What gas do you use in electric bulbs?*

The answer should come at the latest in a few days time:

> *Rolf: Argon is used in electric bulbs. Argon is a noble gas that does not react with other materials. It thus prevents reactions with the wolfram filament, which therefore lasts for a longer time.*

5.5 Diffusion of the PLOT idea

When an innovation is presented it is never adopted without difficulties. This was also the case with the laboratory tasks and teachers' guides for the primary school teachers. The problem for the PLOT members was how to speed up the rate of diffusion. Therefore it was necessary to find the reasons for why the primary school teachers did not immediately adopt the laboratory tasks.

Diffusion can be defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers 1995, 5). The characteristics of an innovation determine the rate of diffusion. If an innovation can be

seen as *advantageous* (Rogers 1995) in comparison with earlier practice, as subjectively perceived by the individual, the rate of adoption will be more rapid. The laboratory tasks and problem based learning activities were objectively, by school authorities and administration, seen as being in accordance with the curriculum and therefore recommended for use. However, the primary school teachers felt that their duty was to teach facts. This they expressed clearly during the work shops.

> *Teacher 1: But then, when you have got the results, you have to formulate them in some … clever way.*
>
> *Teacher 2: I think this is partly the idea in the lower grades with these discussions. It is not really the experiments that are important.*

The problem was that they did not know "the facts". The PLOT members tried to convince them that an open discussion with unanswered questions would do, but without much success. For the primary school teachers it was hard to accept that they as teachers would not be experts in their subjects. The in*compatibility* (Rogers 1995) with existing practice would demand a change in the way of understanding their job. What would their students think? What would the parents say? It did not help in the least that the PLOT members explained how impossible it is to know facts in physics and chemistry. The accuracy of the knowledge may increase all the time, but it will never be complete. These circumstances did not suite the norms of the social surroundings in primary school.

Even if most of the primary school teachers were acquainted with the use of computers and the Internet, there were a few that did not know how to use them and some felt rather insecure in web surroundings. All PLOT material, however, was offered on the web. Thus it was conceived as difficult to use. This *complexity* (Rogers 1995) of understanding and usage was even more pronounced, when the discussion forum was introduced to the primary school teachers.

An innovation that has some degree of *trialability* (Rogers 1995) feels less uncertain, as it is possible to learn by doing. In this sense the work shops offered primary school teachers who were interested to try the laboratory tasks a possibility to do so in secure surroundings. Also the teachers' guides on the web were intended to diminish the uncertainty.

Teacher 7: I had shown, yes, what normally happens when you put sodium bicarbonate and water, that there is a reaction and that a gas develops that needs more space and then there is an explosion.

Teacher 9: Yes. My student had done it at home and it had hit the wall very hard.

Teacher 8: How did you …? You were not afraid that …?

Teacher 7: Yeah. I was keeping it this way because I knew that it would fly, so of course I kept it …

Lotta: It is very important that one considers …

Teacher 8: Just this sort of experiments …

Lotta: … all sorts of rules for work security …

The *observability* (Rogers 1995) of the results of an innovation also increases the diffusion. The PLOT team has continuously published results from their work. The first students that together with Lotta have tested the laboratory tasks have now left secondary school. Some results of their learning are presented in section 5.4. A comparison with a parallel class, which had been taught according to traditional methods, shows both advantages and disadvantages of the PLOT method. The students from the "normal" class have a more profound knowledge of facts. But when it comes to use what they have learned in as good a way as possible to solve new problems, then as expected the class that has learned by problem solving has an advantage. Below one task in a common test is shown together with two answers.[23]

Task: How can you explain that the metal on your bike's handle feels much colder than the plastic handle bars even if both materials have been outdoors in the same ten degree autumn air?

Class 7C: a) Metal conducts heat much quicker and better. Metal is cooled and heated quicker, that is why it feels colder. It also conducts electricity very well. The outer electrons in the metal atoms are used jointly.
b) Different materials are cooled down (and heated) at different speeds. The metal on the bike handle was cooled down quicker and thereby also was colder. Plastic is also softer than metal and stays warm for a longer time.

Class 7E: a) Because metal conducts heat and cold better than plastic.

23 I chose the most and the least satisfactory answer from each class.

b) Metal contains substances that are cold and feel cold. Colder than plastic.

It is noticed that neither class could give a perfect answer. But it is evident that the problem solving class 7C is more open for taking into account all possibilities they find that could have connections to the problem. Class 7E just give an answer they consider to be a fact.

The results of the PLOT method have been published on conferences and seminars both in Finland and abroad (Dumbrajs et al. 2002a; Dumbrajs, Glader and Hartikainen. 2002b; Dumbrajs, Glader, Helle, Rosenblad. and Federley 2003; Bergström-Nyberg et al. 2003; Dumbrajs 2005) The latest publications were also available on the web page of the PLOT project. However, these are not primarily directed to primary school teachers. Communication channels that have been used are the workshops and seminars and courses where PLOT members have lectured. Diffusion occurs more effectively between individuals who are similar in some aspects (Rogers 1995, 19). The subjective evaluation of near-peers will influence the decision to adopt or reject a new idea. Therefore the PLOT team has had an advantage in counting Lotta, a primary school teacher, to its members. She has industriously worked as lecturer and work shop organizer in order to spread the idea of PLOT among her peers.

5.6 Ethic aspects

During the whole research process I reflected on how to secure the anonymity of the interviewees, teachers as well as students, and how to protect them. It is not always enough to change the names of the individuals. In a small school like Mattliden everyone knows who the experienced male teacher of physics is. However, the teachers in the PLOT team did not think that this was a problem. Some of them even wanted to appear under their real names. The primary school teachers that took part in the workshops were better protected. Even I did not know their real names or from which primary school they came. They were informed about my study from the very beginning and no one had any objections to the tape recorders on their tables. Of course I took care

that those parts of the videotapes where they appeared were used only for my own analysis.

When the primary school class from Vindängens skola, in which we had tested the laboratory tasks, started their study in Mattlidens skola, the principal informed the parents about my research intentions. This happened on the first meeting for parents of 7th graders at the start of the first term. No one refused the consent to use the material, i.e. notes and logbooks, or to the audio and video recording of lessons. Of course it was made clear that the anonymity of the students was guaranteed.

Both teachers and students had the possibility to comment on the material to be published. From the first draft on my study was available for anyone to read on the web site of the PLOT team. On request I could also deliver transcripts of all tape recordings. I asked the PLOT teachers to read the transcribed interviews and comment on them. Both teachers and students responded to my study in a very positive way and seemed pleased to be involved in the process.

5.7 The end of this narrative

Telling narratives, as complementing explorative dialogues are processes that create information. Narratives allow individuals to walk in the steps of others and to participate in their meaning making. The individual and the social are intertwined. Individuals make sense of the world and of themselves through narratives, both by telling them and listening to other peoples' stories. The narrative is a fundamental means for people to experience their lives. Human experience is always narrated, and human knowledge and personal identities are constructed and revised through shared narratives. (See e.g. Hänninen 2000, 20)

Knowledge, skills and performance are not static, but developmental in accordance with increasing and changing experience. Individuals in a team must be capable of adapting themselves to the changes in the demands on performance. Continuous learning is an essential aspect of team development. Learning is a way of finding meaning through new

ideas and experiences. A hermeneutical spiral movement occurs as these are grounded in the discursive process and questioned from different perspectives.

Such teams as described above are rare at school. But they exist. We noticed that our team performed very well when the self-regulated work concerned problems that we ourselves had an interest in solving. We performed research in our own work when we developed new teaching methods. Also students that already know each other well can, if they are allowed, form a high performing team. This can happen in sports, but also for example spontaneously in optional courses, where the students follow their own interests. When a teacher is using PBL as teaching method and allows a group of students to work together for a longer period, a culture of teamwork and innovation might develop.

The fabula or plot of the sequence of events composing a narrative can be summarized with Paul Ricoeur's words: " … a story describes a sequence of actions and experiences of a certain number of characters, whether real or imaginary. These characters are represented in situations, which change … [to] which they react. These changes, in turn, reveal hidden aspects of the situations and the characters, giving rise to a new predicament which calls for thought or action or both. The response to this predicament brings the story to its conclusion." (Ricoeur 1981, 277) Has this narrative reached its end or is there a new sequence to come? Will there now be a positive response to the efforts of the PLOT team, when we have given the ball on to The National Board of Education?

6 Discussion and evaluation

The original purpose of this work was to try to meet the demands posed by the new national curriculum that should be taken into use no later than in 2006 and according to which physics and chemistry should be taught as separate subjects already in grades five and six of primary school. During the process the focus was shifted towards the learning process itself and school as a learning organization. At the beginning students' learning in groups, students' motivation and understanding of their own learning was seen as most important. But also the teachers who tried to implement problem based learning as a teaching method noticed that their way of thinking changed; they learned how to teach. This process, learning as an implication of working together as a team, became the most important part of my study. The teachers' experiences of the workshops they organized for primary school teachers were especially valuable considering present and future action. The different culture of primary schools when compared to secondary schools became visible. As the primary and lower secondary schools now are combined to a comprehensive school this difference in culture must be recognized.

The material (see Appendix IV) for physics and chemistry instruction in grades five and six that the PLOT team produced can be considered an innovation that responds to "legislation and other top-down initiations" (Tella and Tirri 1999). It includes the ideas of novelty, as the material is presented in a new way, with incitements to creativity, suggesting a PBL approach to instruction. It contains a suggestion for progress or betterment of the school intern curriculum. It empowers students and adapts them to work under changing circumstances.

The concept of learning emerges as constructive and can be understood as a by-product of participation in a social practice (Engeström 1999, 250). Learning occurs through the dialectical movement of action and reflection as learners move outward into the external world and inward into themselves (Kolb 2002, 91). In a strict sense knowledge is created only by individuals. It is dynamically constructed through interaction between the learner and her environment. The learner experiences herself as an active agent, a creator of knowledge. Knowledge cannot be stored

in static representations and therefore it cannot be transferred; only reconstructed (Bliss and Säljö 1999, 254). It needs to be understood in terms of a microculture of praxis; it is distributed in tools and ways-with-words (Bruner 1996, 132). No absolute knowledge is possible; it is always a reflection of the knower's history of structural transformations (Maturana and Varela 1980, 119). As there is no absolute knowledge there is also no absolute truth. – This view of mine of learning, knowledge and truth has slowly developed during the process of the present study, partly by influence from the literature I have read in order to be able to interpret features revealed in the investigation, partly as an understanding of what is going on inside myself, the PLOT team members, primary school teachers and our students.

6.1. Main results of the study

The PLOT team was formed in accordance with the procedure presented by Wilemon and Thamhain (1983) and discussed in subsection 3.5.2. For me it was a privilege to work together with the PLOT members and to be allowed to follow their development as learners and teachers. I deeply admire the courage and commitment they showed in taking responsibility for their work. The sense of belonging together and the experience of trust and tolerance (subsection 3.3.3) brought great benefits to the team members. Good communication to associations outside the school world (subsection 3.2.4) PLOT members experienced when collaborating with Tekniska Föreningen i Finland (The Technical Society in Finland). The support of the principal in Mattlidens skola and of the board of education in Espoo also encouraged the teachers to strive for success. - In the following I will give a short summary of the results of my research.

How do teachers experience their own learning when they together try to improve the learning process of their students? Subject teachers in the PLOT team changed their way of instruction (subsection 5.3.2). None of them had used PBL as a method of instruction before joining the PLOT project. They now tried to implement PBL in their classes. They allowed the students to influence the teaching and took them into account more

than earlier. This process was rather difficult for the young teacher, Lena, as she had no practical experience of working as a facilitator. She felt herself being in deep water. Primary school teacher students get both theoretical and practical instruction about PBL as a teaching method, but many subject teacher students do their practice in schools, where PBL is not used. Lena took part in seminars on problem based learning to gain more security. However, our version of PBL (Dumbrajs 2001, 21) included open-ended tasks and the principle not to supply the students with "facts" at an early stage of the problem solving process. Here Lena felt insecure. The older subject teachers could lean on their experience as teachers when introducing PBL and therefore were more successful and also more satisfied with their own learning. As accounted for in subsection 5.3.2 teachers expressed the wish to develop the PLOT principles in their schools and encourage their colleagues to adopt the method.

The description of school as a learning organization emphasizes the importance of support and understanding when the employee learns to manage in new situations (section 3.1 and subsection 3.2.1). The principal in Mattlidens skola supported future education of PLOT members and our involvements in activities connected to the teaching process. The communication between PLOT members developed the learning process. This is in accordance with Nonaka's view (subsection 3.6.1) that knowledge is a dynamic human process of justifying personal belief. A hermeneutical spiral develops where the learner builds on prior understandings for further interpretation.

Although the board of education in Espoo and the National Board of Education supported the work of the PLOT team, the members would themselves have needed more confidence in their abilities. They had the feeling of not being able to sell their product (subsection 5.3.2).

How do teachers define the team concept? In his study Willman (2001) suggests that disclosing the holistic nature of the team concept can solve conflicts arising between teachers' different aspects of what a team is. Teachers of the PLOT team understood the team concept in rather different ways. Their views ranged from work groups to top performance teams (subsection 5.2.2). Interesting is that they related all these forms to

the every day school environment. Their own team they saw as a real or a top performance team (subsection 5.2.2). The PLOT team was born out of the considerations of the teachers themselves. There existed no outer pressure. Loikkanen (2005) suggests that such a pressure is necessary for change to occur. But will not some teachers feel coercion to change in a situation of pressure? Does this not affect their commitment to the task and thus their willingness to perform? I think each teacher that joins a team in order to introduce a change from the very beginning has to have a personal interest in the task. The pressure has to be individually internal. Only in this way a real team can come into existence. Different team definitions are described in section 3.5. The teacher team concept is also investigated in a separate publication (Dumbrajs 2007).

How do the teachers describe their experience of working in a team? The PLOT members experienced working together in a very positive way. This could be seen, for example, from the fact that they almost never were late to or missed a team meeting. For some of the teachers this was really extraordinary. Our meetings took place at Mattlidens skola and we met approximately every third week. One teacher expressed the importance of our meetings in a very strong way, see subsection 5.3.2, saying that being a member in the PLOT team made it possible for her to endure the work as a teacher. Other teachers liked the possibility to discuss and also investigate the physics behind our laboratory tasks, as accounted for in subsection 5.3.2. We learned to ask ourselves questions at the same time as we introduced enquiry to our students. To experience things together, get confirmation of one's thoughts, to be part of something greater was seen as valuable (subsection 5.3.2).

It seems that working in teams of teachers can be very obliging. However, this depends on the sort of team considered. A real team as the PLOT team, self-directed and with an explicit purpose (see definition in section 3.5.2), where the members feel that they work with worthwhile tasks, and where there is a clear vision of the future, such a team is a richness in life for its members (subsections 5.2.1 and 5.3.2). In subsection 1.2.2 this experience was, according to Senge, accounted for as a result of working in a top performance team.

The PLOT teachers were empowered to develop their work strategies and try to implement them in the Swedish school community in Finland. We were mutually accountable for the results. Thus in our team usually the most suitable member volunteered to perform a task and tasks always were performed on time. Loikkanen (2005) and Willman (2006) both see difficulties to convince some teachers about the necessity of change and commitment to change. It is clear that such teachers will not devote themselves to the tasks to the same extent as committed teachers. Such teachers would per definition not have had a place in the PLOT team. We worked because we wanted to and we enjoyed it. As Vera expressed it: "I would not come to our meetings if I would not like the atmosphere and the work we do".

How do teachers perceive the possibility of dialogue? In subsection 5.2.2 the teachers, in their interviews, expressed their pleasure of sitting together discussing things of common interest. They felt that they could learn from each other and that they got feedback on their work. Quite new ideas could develop when they considered a problem together. Teachers in the PLOT team grew as persons and individuals due to the possibility to mirror their selves in the views held by others. This helped them in listening to and understanding each other. The emphasizing of dialogue for learning and development of a personal identity is important (subsections 3.1.1 and 3.1.2).

Loikkanen (2005) finds that usually all involved teachers did not take part in schoolings organized to increase their knowledge about the change process. It seems to me that the teachers may not have been agents of their own change process although this was the aim of the implementation of problem based learning. The members of the PLOT team were eager to get schooling and sought contact to researchers and educators in order to discuss their own performance.

How do students experience learning in problem solving situations as compared to learning by transmitting methods? A problem solving situation motivates the student intrinsically whereas learning by transmitting methods often is extrinsically motivating (subsection 1.3.1). Students can satisfy their basic need of self-determinative autonomy in

problem solving situations as described in section 1.3. This is noted in the eagerness with which students approach a problem to be solved (subsections 5.3.1 and 5.4.1).

How does the use of prior knowledge influence students' experience of learning? Discussion of prior understandings in the class can form the foundation for laboratory works (subsection 5.4.1; Dumbrajs 2006). It is then possible for the teacher to choose experiments that give answers to students' questions or that can conquer misunderstandings (subsection 5.4.1). Students own the results of their investigations and feel obliged to change their understandings correspondingly (subsection 3.3.3, section 3.6). New problems drive the curriculum (subsection 5.4.1).

Mortimer and Scott (2003, 97) discuss prior knowledge that is at odds with the scientific point of view. They suggest that the teacher either presents the scientific perspective and ignores all other views, or the teacher provides opportunities to consider both scientific and everyday views. My suggestion (Dumbrajs 2006) that the teacher must start with the everyday views held by the students is not considered. If we assume that the young student goes through the same development as has taken place historically, the class room science can be considered as existing on a continuum between everyday knowledge and scientific knowledge. The possibility that science education and classroom science can be usefully regarded as orders of science in their own right should be recognized. The boundaries between scientific and ordinary action may be understood as continuous and permeable. A protoscience cannot easily be dismissed as oppositional to real science, if the field of view is assembled from practices of disciplined observation. (Dumbrajs 2006; Macbeth 2000, 228)

What kind of learning do students approach? The team motivation (subsection 1.3.2) can be at top only if each team member is motivated. Students that on their own would show little interest in learning become motivated by partaking in the work of the team (subsection 3.6.1). However, if the teacher does not actively follow the work of the group and suggest steps to be taken, the motivation of the team and thus the learning might deteriorate. In order to achieve a deep understanding

the role of the expert is very important. This can clearly be seen in the authentic learning situation in subsection 5.4.1. Here the students would not have been able to develop their learning process on their own. They urgently needed the intervention of an expert.

If students learn in an authentic setting and when the foundation for their learning is their prior knowledge, the premises for deep learning are given. The starting point should be given in a wide context that allows for various problem definitions (subsection 5.4.1). As also noted in earlier investigations (e.g. Fyrenius 2005, 292) there is then a risk of getting stuck with the problem. In such cases expert intervention is necessary. In the ideal case deep understanding of the problem and its solution is achievable.

In PBL situations, how does students' social competence develop? Problem based learning as used in the PLOT project gives priority to work in groups or teams (Dumbrajs 2000; 2001, 21). The students should share knowledge (subsections 5.3.1 and 5.4.1). In solving the problem in subsection 5.4.1 students agreed on the reason for the behavior of the metal ball. The communication involved all four students. In section 3.7 also understanding of self and others and conflict solving are included in the concept "social competence". As mentioned in subsection 5.4.1 two of the groups in the test class that learned according to PBL methods worked together until they left the lower secondary school. Their team competencies developed. Also other groups developed social competence. Students felt free and secure in contacting managements, visiting libraries and discussing with experts.

Which are the problems that primary school teachers experience as most demanding, when they start to teach physics and chemistry? Teachers, both in secondary school and primary school, felt uncomfortable and insecure with the new situation and the demands of the new curriculum (anon. b 2004). According to the theory of change (subsection 3.1.2, sections 3.3 and 3.4) such features are expected to occur.

How did the primary school teachers respond to the subject knowledge request? Primary school teachers did not feel that they would be able to teach physics and chemistry without further instruction courses. They

also did not want to be involved in much instruction as they felt that also other subjects in primary school demanded their attention (subsection 5.4.2). However, they thought that their students would react positively to the laboratory tasks that we had developed.

Which pedagogical methods do they prefer and why? Primary school teachers wanted to teach facts. They did not think that performing open-ended experiments, as a way to enlarge the students' skills and knowledge, was the best method of instruction. Their students were assumed to be too young to make investigations on their own. They wanted to teach ready units that worked (subsection 5.4.2).

How does knowledge diffuse in and between schools and concerned instances? The PLOT team had to find knowledge by themselves (subsection 5.3.2). We got almost no information of what steps had been taken elsewhere in order to make the change possible. We knew that books were prepared for primary school teachers, as one of the PLOT members was involved in this work. We also knew that courses for primary school teachers were held, as another of the PLOT members was involved in the preparation. But coordination and an information flow from higher levels to lower were missing (see section 3.2). The pedagogic faculty of Åbo Akademi, for instance, made some work to help implementation of the new curriculum, but teachers out in the schools mostly knew nothing about it. It was also difficult to find ways to pass on information to other teachers both in primary schools and in secondary schools (sections 3.4 and 5.5). The discussion forum on the web was no success. But forums for teachers in the form of resource and information centers are needed. The gap between the culture of primary schools and lower secondary schools was very wide and must be over bridged. (Subsection 5.3.2)

6.2 Comparison to other similar investigations[24]

There are rather few studies of teams in the school community. In Finland for example Mäntylä (2002) and Willman (2001; 2006) have

24 For a review of litterature on science education in general see e.g. Matthews (1994), Bereiter (2002, 213), and Mortimer and Scott (2003).

studied teams of teachers. The first study employs action research and concerns team development during change. The fact that the professional knowledge of the individual team member increased during the research period is considered to be the main result of the study. Willman investigates the different ways in which class teachers describe their experiences of working in a team. He notices a decay of teacher goals and performance. Thus conflicts with the reform efforts arise. He concludes that alikeness, unity, and stability among teachers in teamwork must be emphasized in contradiction to the distributive expertise suggested by theory.

Loikkanen has investigated teachers' experiences of implementation of problem based learning (PBL) in the instructional program of forest economics at Tampere Polytechnic (Loikkanen 2005). She notes that several components of change must occur simultaneously in order that change can be successful. There must be a pressure to change, a clear common view of the goal of the change, capacity to change, and realizable ideas. It was emphasized that a successful change demands the whole curriculum to be rewritten according to problem based learning principles. The teachers should see themselves as agents of the change, not as victims. Their own learning of the PBL strategies seemed to be difficult to achieve. It seems that the teachers did not feel that they owned the process even if they all (N=8) had agreed to implement the change. – Studies of groups or teams among students exist to a larger degree. These studies mostly concern teaching methods, such as cooperative learning, collaboration and problem based learning.

Bennett and Lubben (2006) report the development and key features of context based courses in chemistry, the so-called Salters courses (named after the main sponsor). This project that started in 1983 has grown to include also other subjects, among them physics, and has spread to many countries. The intention at the beginning was to make chemistry more attractive to students aged 13 and above. The initiative to the project was taken by a group of teachers and science educators. No specific framework of pedagogy or educational theory was used. Different perspectives on the selection of curriculum content, on ideas about how students learn, and on how to promote educational change were taken into account.

The purpose was to enhance the students' appreciation of how chemistry contributes to life situations and to help them to understand the natural environment better. The instruction was designed to start with aspects on the students' lives and introduce ideas and concepts only as they are needed (Campbell et al. 1994, 418).

In a much smaller scale the PLOT project has had similar goals. We also relied on teachers to develop the material and plan workshops and on feedback from both primary school teachers and students. The emphasis in both projects has been on students' motivation and attitudes. Scientific ideas were introduced on a need-to-know basis in order to help to explain and enrich understanding of scientific concepts. Such a spiral approach, where the hermeneutic circle is applied to learning, has implications for the development of students' understanding of scientific ideas. In the worst case it may hinder development of understanding of key concepts. However, Bennett and Lubben (2006) report no significant differences in levels of understanding between students attending the Salters courses and those attending conventional courses. This is in agreement with our results (section 5.5).

Chin and Chia (2003) have investigated the use of students' questions to drive knowledge construction in a problem based learning context. They also discussed implications for instructional practice. Macbeth (2000) analyzed an apparatus for conceptual change in the context of a science education program. He emphasized that students should be given opportunities to test their own hypotheses and theories experimentally. In this way they develop skepticism towards first impressions and learn scientific thinking. (Macbeth 2000, 228) These results are in agreement with ours (subsection 5.4.1, see also Dumbrajs 2006). Problem based learning in communicative teams gives the learner an autonomous role in which she directs her own work. She develops creative features in the search for solutions to her problems. Building on prior understanding for further interpretation, a hermeneutical process of growth and change develops.

Primary and secondary teachers' planning and implementation of a new outcomes-based science syllabus was studied by Appleton and Harrison

(2001). Just like we did, they noticed that teachers who teach outside their main area of expertise prefer to use activities that work. They concentrate on resources needed and on what the students should do in each activity; thereby they neglect crucial points of pedagogy. Outcomes, working scientifically and conceptual learning are not considered. They adapt earlier, often language-based, teaching practices to fit the new situation. Primary science teachers are professionally isolated and their need of supportive partnerships is evident. However, they themselves are reluctant to seek help. (Appleton and Harrison 2001)

6.3 Evaluation of the research process

According to Guba and Lincoln (1994, 107) a paradigm can be seen as a set of basic beliefs that concerns conclusive first principles. A paradigm describes a worldview, the individual's place in this world and her relationships to the world and its parts. In an autopoetic process norms are developed that define the boundaries of the paradigm. These boundaries are not confines, but shape the space for growing (Kolb, Baker and Jensen 2002, 64-65). The researcher will need to locate her discussions of validity and reliability within the paradigm that is being used. In action research, including phenomenography, I find it necessary to discuss reliability, authenticity or internal validity, transferability or external validity, objectivity, and catalytic validity (Lincoln and Guba 2002, 205; Cohen et al. 2000, 226, 123).

6.3.1 Reliability

The reliability of qualitative research is a necessary precondition for validity. If the researcher is able to make the same observations at another time or in other circumstances, she can assume reliable observations to have stability. In this study this was not the case. However, consistent, although time dependent data were gathered over a period of three years and the interviews were made sometimes during a break at school, sometimes in a car on the way home, sometimes in a hurry and sometimes in a situation more like leisurely chatting. Observations

of the interviewees both at school, during evening meetings and at conferences increased the reliability of the observations. These parallel forms of observation were interpreted in conformity with each other and with the interpretations of the interviews. I consistently used those methodological solutions that I found most applicable in the situation for all informants in a group. Documentation and a running account of the process of inquiry stands to the disposal of the reader. A parallel analysis of the data was not performed. It is quite possible that another researcher would have interpreted the material differently. My goal was not to produce a standardized set of categories that any other researcher could have produced. I wanted to produce an illuminating description of a change process. Then use of external investigators becomes controversial. Their involvement in the study might be too superficial to yield deep understanding. However, I urged the interviewees and observed individuals to read and comment on the interpretations. In this way we reached agreement about the occurred events. (Cohen et al. 2000, 119)

6.3.2 Authenticity

For validity of qualitative research understanding and authenticity are main concepts. Validity may be considered through honesty, dept, richness and scope of the data achieved, the participants approached, the extent of triangulation and the objectivity of the researcher (Cohen et al. 2000, 105-106). The researcher is part of the researched world. The instrument to understand human life is another human being. In such a doubly hermeneutic exercise it is necessary to understand the other's understanding of the world. This means a risk of human errors in all its forms. I analyzed data inductively rather than using a priori categories and representation took place in terms of the respondents' descriptions. Respondents or interviewees validated my interpretations.

I have devoted much effort to the question of authenticity of the data, i.e. the ability of the researcher to report a situation through the eyes of the participants. Of course, no replication of interviews or questionnaires could be done, as the possibility that data change with time is built into

the research questions. However, the findings have to make sense and show consistent trends.

Investigator triangulation refers to using more than one investigator in a research setting. However, the very notion of triangulation assumes that a single unit can be measured more than once and thus does not apply to emergent, fluid, specific or unique events, such as investigated here. Investigator triangulation does not necessarily increase the validity of the results, particularly in reflective inquiry. (Cohen et al. 2000, 115)

A native English teacher has partly checked the quotations in the text, originally expressed in Swedish and translated to English by me. Especially the translations of quotations from children's accounts have been controlled according to their relevance, as small children do not always express themselves grammatically correctly. A native Englishman can, however, easily find corresponding English expressions that answer the intended meaning of the Swedish utterance.

My own role as a member of the PLOT team and as a researcher can be seen as problematic. I almost certainly influenced the actions of my informants and my interpretations are subjective. On the other hand my presence in the team helped me to understand the process my colleagues underwent. For an outsider it would have been difficult, if not impossible, to distinguish problems and interpret experiences. Therefore, instead of relying on investigator triangulation, I urged my informants to take an active role in controlling and interpreting my results. This they also did.

The contexts of the research and my own role as researcher have been made explicit. The interpretation of the interviews is transparent, grounded in the data, and supplies the code words, which are then linked to the theoretical discussion and previous studies. A focus on the different views of the informants was sustained throughout the study. After achieving the results of the phenomenographic studies I went back to the original data and tagged the presented utterances with the pseudonyms of the PLOT members. Thus it is now possible to get an insight into individual conceptions.

6.3.3 External validity and objectivity

The validity of the research results is mainly based on the process of data analysis. This is not objective; there is a mutual influence between the researcher and the informants. The researcher's preunderstandings and tacit knowledge influence the interpretations. The problem solving process and reflection over results form critical stages in the interpretation. The categories are grounded in the data. After the first phase the literature influences the choice of categories. Theoretical issues are included in the discussion of the findings. The research findings have been discussed with colleagues at several conferences (e.g. Bergström-Nyberg et al. 2003; Dumbrajs et al. 2002b; 2003; Dumbrajs 2005). My review of actual literature on the topic can be seen as a dialogue with the text of other researchers.

Although the case I have studied is unique it is possible to transfer the perspective on the present situation to other, similar, contexts. Therefore I have tried to give a thick description of the situation. Those events that, perhaps, should not be reduced to simplistic interpretations can be interpreted once more under a different perspective.

6.3.4 Catalytic validity

Catalytic validity describes how well participants are guided to understand their worlds in order to transform them. (Cohen et al. 2000, 111) This research focused on what could be a possible future and what might be future trends and new innovations. The catalytic validity was strong especially when young teacher participants were concerned. They decided to implement problem based learning in their teaching. All teachers found that they had changed their way to consider the interests of their students and their own tasks as teachers.

6.4 Validity and reliability in interviews

Open-ended interviews, which I have used, are narratives, the telling of a story. Narratives are composed of unique sequences of events, mental states or happenings involving human beings as actors (Bruner 1990, 43; see also Hänninen 2000). The interpreter has to comprehend the narrative's plot configuration in order to make sense of its constituting events. But the succession of events determines the plot configuration. We move in a hermeneutic circle. The function of a story is to find an intentional state that makes a deviation from an accepted cultural pattern understandable (Bruner 1990, 47). This achievement gives the story its verisimilitude; it becomes lifelike. Stories have to do with how participants interpret things, what things mean to them (Hänninen 2000, 108).

A relationship between interviewer and interviewees that transcends the research will promote a bond of friendship, a feeling of togetherness. The desire to know, to understand each other's views, to listen to each other's stories and understand each other's feelings will then be a motivation for the research. The aim has to be to secure what is in the minds of the interviewees as unaffected as possible (Cohen et al. 2000, 268). As the interviewees considered me a peer, a large degree of reciprocity might have taken place. The interviewees might have given answers that they thought I wanted to hear. Thus I had some influence on the interviewees and, thereby, on the data. Neither can I completely exclude a tendency to seek answers that supported my preconceived notions. An interpretive study that seeks to understand the world in terms of actors is subjective. The results are not generalizable except where others see their application. Crosschecking is difficult, which easily leads to selective, biased and subjective results.

Analysis of the data is from the very start interpretive; already the transcription is decontextualized, an abstraction from time and space. The social, interactive and dynamic dimensions of the data source are lost. Because of the unstable conditions there is no possibility to achieve reliability. The analysis will become a reflexive, reactive interaction between the researcher and the decontextualized data.

Dialecticism involves a dialectic development of the research text. The interviewees are given the possibility to criticize the text and this criticism must be taken into account. The aim of the research is to reflect the different perspectives of the partaking persons. I urged the PLOT members to read the transcribed text of their interviews and to comment on content and meaning. They read the interpretations and commented on my conclusions. I also reflected over the text and the different opinions emerging. It happened that I had to change my own preunderstandings in face of the different aspects brought forward. As the team members were coauthors on the methodological papers we published together (Bergström-Nyberg et al. 2003, Dumbrajs et al. 2002a; 2002b; 2003), they were used to taking responsibility for the published text. In this sense I feel confident that the text is authentic.

Triangulation of different narratives concerning one special situation will give hints for possible explanations of this situation. If there are only few hints, it is possible to construct several possible stories. The hints can be combined in different ways. The more hints to the same explanation there are, the more convincing the final plot will be. But there is also a human element involved in the comparison of narratives: scientific research can never reach complete certainty. (Hänninen 2000, 28-30, 109-110)

Hänninen (2000, 119) evaluates the narrative on three different levels grounded on experience, action and social intelligibility. When asking whether the narrative succeeds in making life meaningful, in being edifying, the goodness of the inner narrative is assessed. The degree to which the narrative encourages and motivates action, thereby realistically taking into account available opportunities, measures the empowering impact of the narrative. Finally, the narrative's emancipative strength, i.e. its ability to open new perspectives, is a central criterion of goodness on the social level. According to Hänninen's definitions (2000, 107) my interviewees' original thoughts could be understood as inner narratives. The very start of the PLOT project can then be seen as a result of the edifying influence of making the inner narratives external. The dialogue between the PLOT teachers helped us to change our inner narratives. We found motivation to try to alter the present situation; we felt empowered.

New perspectives opened in front of us; we felt emancipated to form our own community of learners. (Hänninen 2000, 106-124)

6.5 Relevance of the work

Narrative research can be considered as a way of supporting creative processes. This takes place, for example, by supplying alternative ways of telling a narrative and by encouraging readers to reflect over their own understanding of the narrative. Changes in life situations invite to a search for new, unusual interpretations and evaluations.

This study has strongly influenced the work and way of thinking of the teachers in the PLOT team. It has contributed to the realization of their potential abilities as teachers, instructors and facilitators. It has also revealed difficulties in implementation of open inquiry in the science curriculum, especially in primary schools. The culture of teaching facts that prevails among primary school teachers stands in contradiction to open inquiry, according to which all starting points are meaningful to the learner and need to be used by the instructor. The PLOT method with its use of external expert knowledge has also opened the door to a deeper collaboration with the enterprise sector, especially with technological companies and organizations of education.

Teams have a central role in the knowledge creation process. They supply a shared context for interaction in which new points of view are created through dialogue (Dumbrajs 2007). Thereby tacit knowledge becomes explicit; explicit knowledge is linked together; internalization takes place. (Nonaka and Takeuchi 1995, 56-71) My present work over teachers' improvement of their own teaching is clearly a topic of significant interest and value for the ongoing change process in our schools, especially as the subjects work in a self-regulated team. Investigation of such teams in school surroundings is new and can contribute to the development of a new teaching and learning atmosphere. P. Johnson (2004), investigating teachers' participation in development of the comprehensive school, found that cooperation and teamwork was used inappropriately in the change process. The building of teams, the team roles, configurations,

and tasks were changed irregularly not taking into account that the development of team features might need a few years of time. There was no empowerment of the teams. The teachers felt confirmed in using their earlier ways of teaching. This shows how important it is that a team can develop without external pressure. Only then the will to learn, the will to improve and change can be totally intrinsically motivated (Dumbrajs 2007).

The communication between team members and between teams has been considered as a means of developing the learning process of the organization (Senge et al. 2000). Knowledge is not just information, facts. It is also a dynamic human process of justifying personal belief. Knowledge, skills and performance are not static, but developmental in accordance with increasing and changing experience. Individuals in a team must be capable of adapting themselves to the changes in the demands on performance. Continuous learning is an essential aspect of team development. Learning is a way of finding meaning through new ideas and experiences. A spiral movement occurs as these are grounded in the discursive process and questioned from different perspectives. I hope that the large potential resources that exist in individuals could be allowed to develop into creative, innovative teamwork at schools. This would prepare the students for the demands of the knowledge society at the same time as their teachers would develop into learning and knowing facilitators and guides, experiencing the wonders of each new day at school.

6.5.1 Implications for future research in education

Willman (2001, 198) suggests that teachers' use of language should be examined in order to disclose new perspectives on their work. This leads to a narrative research approach such as taken by Syrjälä and Heikkinen (2002) and by myself in this study. Syrjälä and Uitto (2004) investigate practices of instruction by examination of teacher narratives. Keinonen (2005) studies graduating class teachers' views of teaching and learning. Teacher narratives are of importance whatever discerning features one wants to describe in teachers' communities. Not only do we receive a compilation of researcher narratives that can give a holistic picture of

the event, but also the teacher is offered a possibility to reflect over her situation and her future aspects.

In this study I described the development and learning of teams. The research of teacher teams is still scarce and most investigations concentrate on work teams (e.g. Mäntylä 2002; Willman 2001). According to Willman (2001) different change models proposed by literature (e.g. Sahlberg and Sharan 2001, Senge et al. 2000) have seldom been applied as such. Implementation of a change of teachers' professional identity is delayed due to fear of the unknown. There are discussions on how to empower teacher teams, but few reports on successful top performance teacher teams at school (anon. g. 2004). It would be of interest to enlarge the research, especially on empowered, self-regulated teacher teams at schools (Barnett, McKowen and Bloom 1998). Such research is very scarce. What influence would such teams have on the socio emotional relations in teacher communities? Would the work satisfaction and motivation increase? It would also be of interest to find out how such features as stress, self-worth, ownership of work, sense of belonging, and attitudes depend on team parameters, such as performance and vision. To what extent do communication and interaction in teachers' community depend on the existence of teams? Do teachers in teams experience dialogue as learning in a deep sense? Can conversational learning in teacher teams expand the capacity to deal with change, complexity and difference? These are questions that arise out of my investigation. A holistic view can be achieved only by undertaking further investigations.

Students also work in groups or teams. How do teachers use students' prior knowledge when they introduce a new topic? And how do students use their prior knowledge, when they formulate their beliefs? Often, the ways of talking, making arguments and developing theories, which are thought to constitute science, are seen as distinct from the linguistic and social practices used in everyday life (Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes 2001). Mercer (2000, 160) emphasizes that a necessary prerequisite for a learning conversation is enough prior shared knowledge to be able to achieve an initial joint understanding. Rather than asking many questions, the teacher should invite students to share their own thoughts.

6.5.2 Implications for future educational contexts

Could the above-mentioned studies implicate that narratives form a fundamental structure of all learning? The most effective way to reach learners with educational messages is through narratives. Narratives educate as instruments of transformation, but also as information. I think that drama and story telling should be part of teaching to a much higher degree than today. Such a perspective does not only involve story telling in the classroom, but also leads to a constructivist pedagogy based on experience. Teaching strategies that involve dialogue and team work go beyond the knowledge of facts. The learner enters into the world of the narrative and creates as well as discovers meaning. She poses the questions she needs to answer. In such a perspective integration of subject contents will be natural. Learning will be viewed in a holistic way. This again will lead to curricula that contain blocks extending over hours, maybe days, during which one topic integrated over many subjects will be dealt with. I think we will have this sort of curricula in the future to a larger extent than today. The effect of teaching in a holistic way should, however, be more thoroughly investigated. Will students be able to cope with their world in a better way after attending integrated learning?

With the earlier mentioned seminar in Mattliden in the year 2003 a step was taken towards collaboration between teachers and researchers interested in developing pedagogy and teaching methods. Schools started to invite PLOT members to present their method of instruction. The National Board of Education invited PLOT members to lecture. They were also invited to take part in new activities of pedagogical development. Mattliden's school became, for example, involved in an integration project including all instructed subjects and most of the teachers. The theme of our project was "Color". The subject teachers found the connections of the theme to their own subject. For example, in religion students were introduced to the colors of the liturgical year. In chemistry color indicators were discussed, and in physics the rainbow and refraction of light. (Dumbrajs 2004, Andersson and Hagström 2005)

The prosperity of our country depends on a constant development of good science and technology knowledge and of innovations of these. The seed for the needed innovative and creative way of thinking must be seeded already in comprehensive school. The PLOT members therefore decided to arrange biennale Seminars around Innovations and Creativity in education (SIC). The intention is to give teachers and representatives from the enterprise sector, institutions and universities a possibility to meet and to supply teachers with inspiration and ideas in order to develop their work with their students. The first seminar of this type took place in February 2005 in Arcada polytechnic in collaboration with Tekniska Föreningen i Finland (The Technical Society in Finland) and the National Board of Education. Lecturers were national and international experts. The second SIC seminar was held in February 2007. This time the main theme was "energy".

The teachers that took part in the above mentioned seminars have foremost appreciated the possibility to enlarge their understanding of demands from industry and enterprises to provide students with appropriate knowledge and the offer from them to help in supplying this knowledge. From the beginning of 2007 resource centers for teachers start their work in Helsinki, Vaasa and Turku. These centers, developed on initiative of Svenska Tekniska Vetenskapsakademien in Finland, supply teachers of mathematics and natural sciences with possibilities for further education and development of teaching, especially in thematic entireties oriented towards technical training and education. To create contact networks to teachers in the region, to organize study circles and to build relations to nearby industry will be the primary tasks for the centers in all three sites. Investigation of the performance of such networks will be of great interest for the future development of school curricula and collaborative enterprises. The need to collaborate in adapting the learning contents of comprehensive school curricula so that students are prepared to cope with life issues and demands has been recognized worldwide. On the home page of UNESCO one can read: "The relevance of learning content is central to the economic and social development of a nation. The curriculum needs to satisfy labor market demands while inculcating responsible citizenship in democratic, inter-dependent communities." – "Teaching and learning methods as well as leadership styles are naturally

in need of renewal to provide quality and relevant secondary education in response to the advancement of knowledge and renewed curricula." - "Regional and international cooperation will be fostered through networking and exchange of information."

> Dieses Seiende ist weder vorhanden noch zuhanden, sondern ist *so, wie* das freigebende Dasein selbst – es ist *auch und mit da*.
>
> (Heidegger 1927, 118)

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APPENDIX I

Questionnaire for teachers involved in the PLOT-project:

Date: _____

1. For how long have you worked as a teacher? _____

2. On which level do you teach? _____

3. What knowledge about problem based learning did you have before you got involved in the PLOT-project? _____
_____
_____
_____
_____
_____

4. What do you think is central in teaching physics? _____
_____
_____
_____
_____
_____

5. How do you understand the pupils' process of learning? _____
_____
_____
_____
_____
_____

6. Is problem based learning a useful method? Why / why not? _____
_____
_____
_____
_____
_____

7. What qualities are asked for from the teacher, who works with problem based learning? _____
_____
_____
_____
_____
_____

8. How do you experience collaboration with other teachers in the PLOT-project, teaching a) on the same level b) on a different level? _____
_____
_____
_____
_____
_____

APPENDIX II

Questionnaire for primary school teachers participating in the PLOT-project workshops:

Date: _____

Kindly answer these questions before you start the laboratory tasks.

Your education in physics:

- Upper secondary, obligatory course ☐
- Upper secondary, more than obligatory ☐
- University, approbatur ☐
- University, cum laude ☐
- University, laudatur ☐

Your education in chemistry:

- Upper secondary, obligatory course ☐
- Upper secondary, more than obligatory ☐
- University, approbatur ☐
- University, cum laude ☐
- University, laudatur ☐

Teaching experience in physics:

- None ☐
- Some ☐
- Rather much ☐
- Much ☐

Teaching experience in chemistry:

- None ☐
- Some ☐
- Rather much ☐
- Much ☐

Do you use problem based learning and/or investigative methods in teaching?

- Not at all ☐
- Sometimes ☐
- Often ☐

Kindly comment on the laboratory tasks after you have completed them.

Laboratory tasks for the students:

How do you think your students would react on them? _____ _____
_____
_____

Are they useful for you as a teacher? Why? Why not? _____
_____
_____

What could be improved? _____
_____
_____
_____

The teacher's guide:

Is some information you might need missing? _____
_____
_____

What could be made more clear? _____
_____

Do you think you will use the teacher's guide? _____
_____

What do you think about a teacher's guide on the webb?_____
_____

If you were going to use the PLOT material, would you then also allow the students to investigate themselves and you yourself function more as a tutor than as a teacher?_____
_____
_____

How do you like the idea of keeping a logbook (portfolio, notepad that follows the student to secondary school)? _____
_____

Some more comments? _____
_____

APPENDIX III

Physics and chemistry education of primary school teachers taking part in workshops organized by the team and Espoo city (percentage of teachers):

Physics	29	43	7	14	
Chemistry*	29	29	21	7	
	Obligatory Secondary school	More, Secondary school	University, approbatur	University, cum laude	University, laudatur

* one teacher left this question unanswered.

Physics and chemistry teaching experience (percentage of teachers):

Physics	36	50	7	7
Chemistry	43	43	7	7
	None	Some	Rather much	Much

Use of investigative learning methods (percentage of teachers):

Physics and chemistry		86	14
	Not at all	Sometimes	Often

APPENDIX IV

Laboratory Tasks for Grades 5 and 6

Method

Problem based learning uses group work, discussions, investigative laboratory tasks, students' self-regulated work, lessons, argumentation and reflection as instructional methods. Curiosity is the driving force of exploration and discovery. The young student goes directly to the solution or explanation: "I believe the world is functioning in this way". This belief, or hypothesis, is modified in accordance with the results of empirical investigations. The modifications give rise to new challenges, investigations and further modifications. From the context in which discoveries are made, one goes on in order to justify the hypothesis. For this purpose social activity, discussion and communication are needed. Theoretical concepts arise from reflective abstraction that requires social interaction. Relations between beliefs, facts and justifications are agreed upon in the learning group when different opinions clash.

By performing a few laboratory tasks the students get acquainted to several different regions of physics and chemistry. They should with the help of their teacher and facilitator be able to find new experiments and problems which can guide them in their investigative learning. Our task is to supply the material needed in order to get started. If the students learn to investigate their surroundings in a questioning way and without accepting false or unfinished conclusions, but always being ready for discussions and questioning, it might be possible to reduce misconceptions. It is also important that some questions or problems are left unanswered. Thus the interest is kept alive and the process of investigation continues. It is of use for the students if the results of their work can be saved in a portfolio or a logbook. The students can then later go back to these works and find which questions were left open, where the problem was, or simply which the conclusions were. This possibility to look back will be a great help for the studies in physics and chemistry in coming years.

Please, note:

No question is so unimportant as to not being worthy of a discussion.
Curiosity leads the world forwards – so all great discoveries were made.

1. Discuss the subject of the laboratory task with your students. In the lower grades the level of knowledge is very variable. A collaborative discussion integrates the knowledge to a shared knowledge of the class. All stand at the same line when starting with the task.
2. If it is possible the students should be allowed to work in groups. Ask your students to make notes about how they solve their task and what results they get. Point out that accuracy is important; otherwise the result is not trustworthy.
3. Next the groups should reflect over their result. Was their investigation successful? Could things have been done in a better way? Did they get some result? Will this result help them to understand something in their environment in a better way?
4. Write down the questions that now arise. Do it preferably group wise; then weak students can relay on the knowledge of the stronger students. Are there some new questions? Discuss the questions together in the class.
5. Point out that it impossible to reach a final result in science. Development happens all the time and humans learn to understand better and better. Some questions may remain unanswered.
6. Give the students homework that connects to their everyday life. Ask them to explain the task with help of the experiences they have just made.
7. If one still wants to deepen the new knowledge, one can give the students a project work to do. Excursions can shed light on the problem before or after the laboratory work.

Acoustics

We are going to investigate if it is possible to see and feel sound. We are also going to make an experiment through which we can find out how sound can be amplified and conducted.

Material:
Tuning forks
A beaker with water.

1. Hit the tuning fork with a wooden hammer or stick. Put the fork to the ear and listen. Touch the legs of the tuning fork. Write down your experiences.
2. Pour water into a beaker. Hit the tuning fork with the club or stick. Carefully touch the water surface with the legs of the tuning fork. Write down what you see and why you think it happens.
3. Hit the tuning fork with the club or stick. Put the tuning fork light against your nose. Write down what you felt.
4. Hit the tuning fork hard. Then put its handle bar against different things, for example your desk, the wall, a heating element, a carpet, your jacket, and so on. How is the sound? Put your ear against the thing you investigate some small distance from the fork and listen if it is possible to hear the sound from the fork. Do you hear the sound now? Note down your results in a table under the headings:

Material	**Sound through the air**		**Sound through the material**	
	Well	Badly	Well	Badly

5. Discuss in your group what you think sound is. Do you think it is possible to hear each other everywhere? Is it possible to hear under water? What is echo? Through which material one could hear very well and through which very badly. Is it possible to hear sound through a railway rail?

Teacher's guide:

Goal: How does sound arise and in which materials is sound amplified?
Discussion in the class before the laboratory work: Discuss sound in a general way. Gather the students' conceptions and knowledge about sound. What do they know and what do they believe. Tell them to put their hand on the throat when they speak.
Laboratory tasks: The students work in groups, if possible. Then one tuning fork for each group is needed. A tuning fork thrives, if one does not hit it

with something hard, like metal, but preferably with wood or hard rubber. It is important that the students make notes about their discoveries and also about their thoughts concerning the phenomena. Maybe all questions will not be answered, but this is not necessary. You may contact a subject teacher or wait with the explanation until later.

Discussion in the class after the laboratory work: When the results from the different groups have been discussed one can think about how the ear works. Other questions to discuss may be: How does the sound of a string musical instrument arise? Why one does not hear all oscillating movements? Why do we not hear a whistle pipe for dogs? As an extra laboratory task one can try to build a sound pipe instrument out of five bottles or experimental tubes with different amounts of water in them and then to play "Old man Noah" on this instrument.

Density

With the density of matter one means the weight of the matter (in grams) per cubic centimeter, i.e. how much the weight of 1 cm^3 of the matter is. Water has the density 1 g/cm^3 or 1 kg/dm^3 because 1 liter(= 1 dm^3) water has the weight 1 kg. Wood has smaller density than water because wood floats. A stone has larger density than water.

Take a round apple and a round potato. Clean them well. Investigate if they have larger or smaller density than water.

Determine the density of both as well as you can.

Give to each group of students an equally large piece of modeling material. The students shall try to build a boat of the material. They should try to make the boat such that it can carry as much weight as possible.

Teachers' guide:

Goal:
To understand features of different matters from the aspect of natural phenomena.

Discussion in the class:
Why some matter is heavier than other? Why some things float and other not? Make a spreadsheet of things that float and things that sink.

Material:
Transparent basin, measuring-glass, apple, potato, salt, water and a scale.

The volume can be decided with the help of a transparent basin filled with water. One dips the potato or the apple and gathers up the water that pours over the edge. The volume of the water is measured with a measuring-glass.

It can be of interest to first put the potato in sweet water and then add salt, mix, and get the potato to float. Explain the difference between sweet and salty water. Observe that salt dissolves well also in cold water. (Here a parallel can be drawn to the Dead See and its holding of salt.) Then add slowly and carefully sweet water. The potato stops at the border line between sweet and salty water. Here it is important that the basin is transparent! It works better and is cheaper with quite normal salt for cooking.

Homework:
The student should estimate the density (for example larger or smaller than the density of water) for at least 5 different objects in the surroundings.

To deepen the knowledge:
It is important for the understanding that the experiments are performed also with small pieces of the apple and the potato. Preferably one cuts 1 cm^3 big pieces and determines the weight with the help of the scale, but also a repetition of the experiment with a somewhat larger piece deepens the understanding of the concept density.

One can preferably also decide the density of some other objects, for example wood, stone, different things of metal.

An interesting and amusing task is to give to each group of students an equally large piece of modeling material and small nails. The students shall try to build a boat of the material. They should try to make the boat such that it can carry as many nails as possible.

Material for the teacher: http://na-serv.did.gu.se/nordlab/se/overw/overwB.html#m

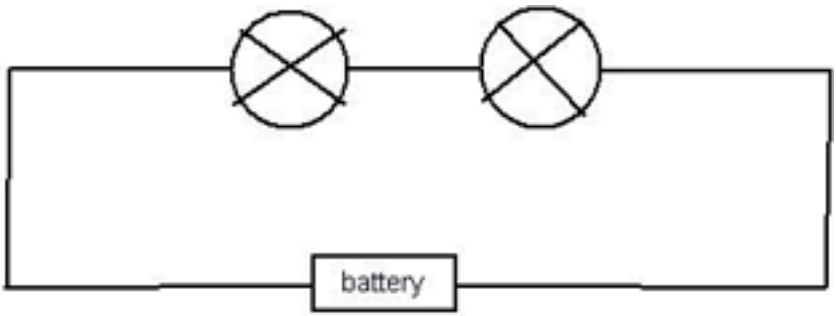
Electricity

Read the instructions, do the tasks, make notes about all your experiences.
Material: A battery for a flashlight (4,5 V), a smaller battery (1,5 V), four electric wires, two red ones and two black, two small bulbs for flashlights, paper clips.

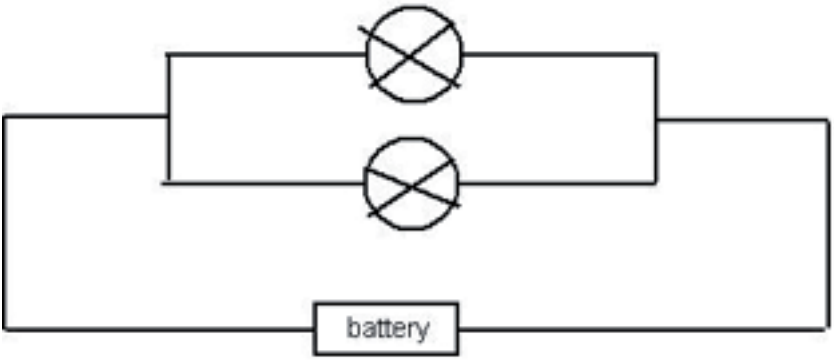
1. Try to get a bulb to light. Describe in your logbook how one has to do it. When does the bulb have a stronger light? Why? Is it important what color the wires have? Which wires should be used? Why?
2. Try to get the bulb to light when the electricity goes through different materials, like a key, a pencil, an erasing gum, a sharpener for pencils, a scissors, a ruler, and so on. What conclusion can you make?
3. Now take two bulbs and the stronger battery. Try to connect the bulbs in different ways. When do they get dim, when is the light almost as strong? Take away one bulb. What happens to the other?
4. What happens if you connect both batteries after each other so that their positive and negative poles are connected? Will it change the strength of the light from the bulb? Why?

Teacher's guide:

Goal: To understand the functioning of the battery and the closed electric circuit. To understand which materials conduct electricity. Parallel coupling and coupling in series.
Discussion in the class prior to the laboratory tasks:
Concepts: Battery, electric wires, electricity, electric circuit, conductor, isolator, coupling in series, parallel coupling.
When the bulbs are parallel connected both are connected to the poles of the battery. Batteries are connected parallel so that the positive poles are connected and the negative poles are connected.
Discuss different sorts of sources of electricity. How do you create electricity with the help of a bicycle dynamo? Can you store electricity? The car accumulator. The flash light battery. Discuss the above concepts without making conclusions. Only collect the students' conceptions.
Laboratory tasks:
The students should work in small groups so that everyone can try to make the couplings. It is important that they make notes of their ideas and of the results of the tests. They must be allowed to try themselves without help of the teacher.



Coupling in series of bulbs



Parallel coupling of bulbs

1. Try to get a bulb to light. Describe in your logbook how one has to do it. When does the bulb have a stronger light? Why? Is it important what color the wires have? Which wires should be used? Why?

Many students think that the color of the wires determines in which direction the electric stream moves. What is it that causes the wires to conduct electricity? Why are the wires colored?

2. Try to get the bulb to light when the electricity goes through different materials, like a key, a pencil, an erasing gum, a sharpener for pencils, a scissors, a ruler, and so on. What conclusion can you make.

Can electricity pass through a liquid? Make a solution of normal salt for cooking. Soak a soft paper towel with the solution. Now try to conduct electricity through the towel. Try also to conduct electricity through a dry piece of paper and through the salt solution in the beaker.

3. Now take two bulbs and the stronger battery. Try to connect the bulbs in different ways. When do they get dim, when is the light almost as strong? Take away one bulb. What happens to the other?

There are different sorts of bulbs. Some do give almost no light, others give a clear light in the same electric circuit. What is the reason for this? Here both 3 V and 6V bulbs are necessary! (It is not necessary to get an answer to this question, but it should come into the logbook for future need.)

4. What happens if you connect the two batteries after each other?

Allow the students to reflect on the phenomenon. What do they think, is it possible to connect the batteries parallel? What happens then?

Discussion in the class after the laboratory work:
The shared knowledge of the whole class is gathered. Which new concepts have the students learned? Did they learn to know more about some phenomenon?
Means to deepen the knowledge of the students: Investigate how a flash light functions.
Home work: Where is isolating material used in connection with electric apparatus at home? Why?
Material for the teacher: Nordlab-Sverige, Göteborgs univ. http://www.fysik.org/didaktik/fysikdidaktik/fysikdid5.asp Nordlab Laborationerna

Mechanics

Study the tasks, perform the work, and make notes of your observations.

1. Material: Smooth surface, for example a Perspex pane, two tiny iron balls of different size, two magnets. If the work is done in groups, each group will need this material.

Try out how a ball (the smaller one) is moving on the surface when you make it move by suddenly thrusting it. Thereupon let the ball rest on the surface; slowly move a magnet in direction of the ball until the ball starts to move. Is there any difference between the two movements?

How is it if you take the bigger ball? What happens if you place a ball exactly in the middle between two equally strong magnets? And if the magnets try to drag the ball in different but not opposite directions?
What happens if the ball was thrust so that it is moving and you move a magnet in its direction? Put the magnet on the surface close to the ball. Let go of the magnet but keep the ball in place. What happens?
Think of some experiments of your own that you can do with the balls and magnets.

2. The falling motion (the experiment may be performed in groups or as a demonstration by the teacher):
Material: Smooth, short planks of wood, paper, and weights.

Let the wooden piece and a small piece of paper fall from the same height. Which one will reach the floor first?
Then place the piece of paper on top of the wooden plank (no protruding edges!) and repeat the experiment. What happens? Why?

Teacher's guide:

Goal: The students learn that forces need to operate in pairs, when the movement of an object is changed. The bigger the impact of force is, the bigger will the change be. Both objects are affected. A continuing impact of force creates an accelerated (or a retarded) movement. Besides, the students get acquainted with magnets and magnetic force.

Discussion in the class before the laboratory work:
Concepts: Magnetism, reciprocation, rest, regular motion, accelerated motion, falling motion, energy.

Discuss these concepts with the students before the laboratory work. Especially talk about magnetism and magnetic force. It is enough to gather the everyday knowledge of the students and make this to shared knowledge. The students may also in groups collect information about the concepts and then compare the results with other groups.

Laboratory work:
If possible the students should work in groups. It is important that they make notes of how the experiments succeeded and what thoughts occurred and which reflections they made. Important is to look backward when the experiment is done and think of what could have been done in a better way. What conclusions can be drawn from the results? Do the results help us to understand also other phenomena in a better way?

1. Material: Smooth surface, for example a Perspex pane, two tiny iron balls of different size, two magnets. If the work is done in groups, each group will need this material.

Try out how a ball (the smaller one) is moving on the surface when you make it move by suddenly thrusting it. Thereupon let the ball rest on the surface; slowly move a magnet in direction of the ball until the ball starts to move. Is there any difference between the two movements?

How is it if you take the bigger ball? What happens if you place a ball exactly in the middle between two equally strong magnets? And if the magnets try to drag the ball in different but not opposite directions?
What happens if the ball was thrust so that it is moving and you move a magnet in its direction? Put the magnet on the surface close to the ball. Let go of the magnet but keep the ball in place. What happens?
Think of some experiments of your own that you can do with the balls and magnets.

The teacher can also perform the experiment as demonstration.

The next experiment can deepen the understanding of the students:

- Constant velocity:
  The students of the class take positions in the corridor with 5-meter distance between each other. One student must walk, one jog, and one run along the corridor. Each observing student has a chronometer that is started when the student that walks passes a start line. The student that walks must have flying start. The different velocities are calculated.

- Acceleration (preferably even):
  A ball is rolled in a ca. 3-meter long tube. Students with chronometers are positioned along the tube and measure the time it takes for the ball to reach the measuring point for the respective student. The inclination of the tube must be small and the ball suitable.

2. The falling motion:
We discuss in the class what sort of things can fall and how do they fall. Let a wooden piece of plank and a small piece of paper fall from the same height. Which one will reach the floor first?
Then place the piece of paper on top of the wooden piece (no protruding edges!) and repeat the experiment. What happens? Why?

The students between themselves discuss the results in the groups until they reach agreement. One student from each group as representative of the group continues the discussion in the group of representatives. A result of the discussion is presented for the class and written into the logbook. It is important that an expert is asked to participate in the final discussion.

The next experiments can deepen the understanding:

- Place a weight at one end of the wooden piece of plank. How do the wooden piece and the weight fall now?
- The students cut equally large circles from hard paper. From the circles differently sized sectors are cut away and the rest is glued together to a cone. The piece that was cut away is put into the cone in order that the masses are the same. Then one allows the cones to fall with the top first and the time taken to hit the ground is measured.

Discussion:
Discuss different sorts of movement with the students. How we can explain the movements of the planets around the sun? How sun and moon darkening arise? What do we mean with the phenomenon rotation?
Homework:
Make notes of at least five different examples of constant motion and accelerated motion that you are in contact with in your daily life. Consider what happens when you throw a ball vertically into the air. What would happen in outer space? Why this does not happen on the earth?
Means to deepen the knowledge of the students:
Discuss with for example the sports teacher about the difference of being a 100-meter's runner or a 10000-meter's runner. Which features and skills are important?

Material for the teacher:
Nordiska resurscentret i fysik. Nordlab-Danmark, article written by Robin Millar.

Optics

Features of the light

Material:
Flash lights
Paper; size A4, white, black and clear red or clear green.
A black-white photography, for example a copy in size A4 of a picture of all the students in the class. Aluminum folio.
A laser pen or a flashlight with a sharp, directed beam of light.
Mirrors.
Candles.
A big, hard pane of plastic through which light can pass.

1. Let a beam of light from a flashlight hit a white, a colored and a black surface of paper. Look at a photo in the light reflected from the paper, not the direct light. Is there a difference? If, then explain the difference.
2. Is there a difference if the light hits a white paper surface or a wrinkled aluminum folio? Look also now at a photo in the light reflected from the paper/the aluminum folio.
3. Let the light beam hit a mirror in different angles. Explain what you notice. Is there some rule? Try for example to hit something with the light beam via the mirror.
4. Lit a candle in front of a mirror and look at it in the mirror. Take the candle closer to the mirror and further away from the mirror while you watch it in the mirror. What do you note?
5. Lit a candle on each side of a big plastic board that is transparent. Both candles should be at the same distance from the board. Stand in front of the board. Someone of the group members blows out the candle behind the board. What do you notice? Do it so many times that all can see the phenomenon.

Teacher's guide:

Goal:
With these experiments one tries to explain and distinguish between the concepts "diffusion, absorption and reflection of light" and the concepts "transparent, opaque".

Discussion in the class before starting the laboratory work:
Before the laboratory work one can together with the students reflect on lightness, darkness and colors and on the concepts that will occur during the work. This can be done for example by gathering the students' experiences and conceptions. This can be done the whole class together or in groups, where the results of the groups will be discussed together.
Laboratory work:
This work can preferably be done in groups. The teacher can prepare for the work by distributing material and a description of each laboratory task separately. The students may then do the tasks at the different stations. It is important that the students make notes of their experiences and that these after the work are discussed together.
Material:
Flashlights.
Paper, size A4, white, black and clear red or clear green.
A black white photography, for example a copy in size A4 of a picture of all the students in the class. Aluminum folio.
A laser pen or a flash light with a sharp, directed beam of light.
Mirrors.
Candles.
A big, hard pane of plastic through which light can pass.

1. Let a beam of light from a flash light hit a white, a colored and a black surface of paper. Look at a photo in the light reflected from the paper, not the direct light. Is there a difference? If, then explain the difference.

   It is important that the beam of light is not directed against the photo, but that one looks at it in the light that scatters from the paper. The black paper absorbs all the light, the colored paper scatters only the colored light and the white paper scatters all light. One can extend the discussion by comparing to usage of white and black clothes in the summer. Why dark clothing becomes warm in the sun?

2. Is there a difference if the light hits a white paper surface or a wrinkled aluminum folio? Look also now at a photo in the light reflected from the paper/the aluminum folio.

   The aluminum folio reflects light in all directions. Compare the strength of the reflected light from the aluminum folio and the light scattering from the white paper. The experiment can be expanded by reflection of light from a mirror.

3. Let the light beam hit a mirror in different angles. Explain what you notice. Is there some rule? Try for example to hit something with the light beam via the mirror.

   Here it is necessary to get a sharp beam. For example put a flashlight into an empty roll of kitchen paper towels. A laser pen also works well. The reflection takes place regularly; the beam hits the mirror at the same angle as it is reflected. The students easily succeed to direct the beam via the mirror on some object in the classroom.

4. Lit a candle in front of a mirror and look at it in the mirror. Take the candle closer to the mirror and further away from the mirror while you watch it in the mirror. What do you note?

   Note that the picture really is not in the plane of the mirror but behind the mirror and that one can see how the distance changes when one moves the candle.

5. Lit a candle on each side of a big plastic board that is transparent. Both candles should be at the same distance from the board. Stand in front of the board. Someone of the group members blows out the candle behind the board. What do you notice? Do it so many times that all can see the phenomenon.

This shows more clearly the phenomenon in point 4. The plastic board must be in right angle to the surface of the table. The plastic board is transparent, but yet a mirror. One has to be careful when adjusting the experimental set up. The easiest way is to lit one candle and then move the other one until it seems that it is burning. Prepare everything before the students are allowed into the class room, then the effect is bigger. Many illusions are using this trick.

Here the candle is placed in the wrong position behind the plastic board. One can see that it is not burning.

Here the candle is in the right position. It looks like both candles would be burning. One can later also lit the other one.

If the students find some interesting features that the teacher was not expecting, it is important to notice these and to try to discuss them. If there seems to be no solution, one can contact a subject teacher. One can also discuss light and shadow. Where is the shadow? Why is there a shadow? From here one can continue to discuss moon and sun darkening.

Refraction of light

Material:
A beaker of glass, pencils, a stone, a basin of glass, a prism, white light from a diaprojector, overhead projector or a flashlight (the light must be in form of a sharp beam), convex lenses (magnifying glasses).

1. Take a beaker with water. Put a pencil into the water. Study the pencil from all directions. What do you notice? Put a small stone into the beaker. Try to hit the stone with the pencil from above the water surface in an angle to the horizontal plane. Do you hit the stone if the angle is kept the same as above the surface? Can you explain the phenomenon?
2. Take a basin with water. Put the stone into the water. Investigate the stone from all directions. Suddenly the stone disappears. Explain the phenomenon.
3. Let a beam of white light refract in a prism. Catch the beam on a paper behind the prism. What do you notice? Have you seen the same phenomenon somewhere? Can you explain how the rainbow arises?
4. Take a convex lens and very thin paper. Try to get the paper to burn. The concave lens also has a burning point. Can this be seen? Can it be used to get paper to burn?
5. Lenses can be used to create pictures. In the eye there is a lens. How does the picture of something one is looking at arise? What is the use of glasses?

Goal:
The student reflects over the light and its features.

Performance of the instruction:
Discussion in the class about the phenomenon light. From where does it come? Movements of the earth and the moon. The time of the day. The length of the day. Periods of the year. Phases of the moon and eclipse of the moon.

Material:
Light source (preferably a lamp giving a sharp beam of light, a laser pen is good, besides when investigating the spectrum of the light), beakers, pencils or similar things (that resist water), small stones, bigger basins, glass prisms, white

hard paper, different sorts of lenses (thick in the middle = convex, thin in the middle = concave), silk-paper, and magnifying glasses.

Concepts:
The following concepts are defined and presented in the experiments: the beam of light, refraction and reflection, the nature of light, dispersion in colors and spectra, refraction of light in lenses, and pictures of objects.

1. Take a beaker with water. Put a pencil into the water. Study the pencil from all directions. What do you notice? Put a small stone into the beaker. Try to hit the stone with the pencil from above the water surface in an angle to the horizontal plane. Do you hit the stone if the angle is kept the same as above the surface? Can you explain the phenomenon?

   It should be possible to notice that the pencil seems to be bent at the water surface. In order not to hit the stone the depth of water should be reasonable, which is not easy to achieve. It is interesting to find out what the students pay attention to. Sometimes they notice phenomena that the teacher has not at all regarded when planning. These should be taken seriously and be discussed, especially if they concern physical occurrences.

   To help the students forwards one can ask them to discuss the beam of light. They can also study pictures where the physical event is shown isolated. Will the students now realize that the beam of light changes direction at the water surface? It is important that the students reflect over the phenomenon themselves. They do not need to understand the physical occurrence. It is ideal, if the students note down both their own conclusions and unsolved problems. Later, when the refraction of light has been under consideration once more, the experiment can be repeated and the students can study their old notes.

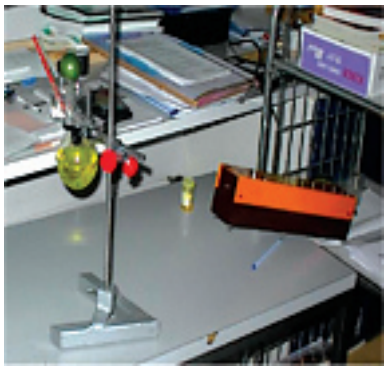
   Complete, if you like, with the following experiment:

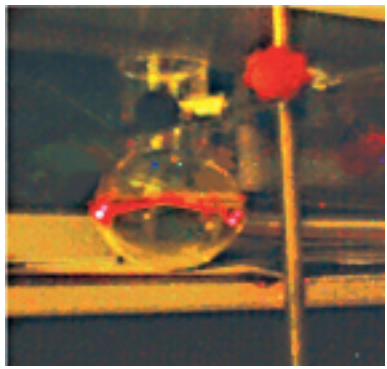
   (1a) Take a beaker with water. Put a test tube into the beaker. Put a pencilinto the test tube. The lower part of the pencil disappears. Put water into the test tube to the same level as it is in the beaker. The pencil reappears.

2. Take a basin with water. Put the stone into the water. Investigate the stone from all directions. Suddenly the stone disappears. Explain the phenomenon.

   Here reflexion occurs. When the stone disappears under certain illumination conditions this is because the water surface works as a mirror. Total reflexion occurs when one looks at the water surface from beneath the water surface. Then a mirror picture of the stone is seen in the water surface. This experiment should be performed only when experiment 1 has been thoroughly discussed. The concept can be further clarified with help of the following experiment:

   (2a) Take a beaker (retort) with round bottom (see picture) and fill half of it with colored water. Send a beam of light skew from below with a laser pen in direction of the center of the retort. If the light hits the water surface skew enough, total reflexion will occur. The angle between the water surface and the beam of light should be smaller than approximately 40 degrees. In a dark room the path of the beam of light is clearly seen.





If one does not have a round retort, one can try to use an aquarium or a big basin of glass. If one sends a laser beam from below the bottom or perhaps from the side up against the water surface one can achieve total reflexion in the water surface. The problem is to get the angle of incidence close enough to the surface. If the beam hits the surface too straight no total reflexion will occur.

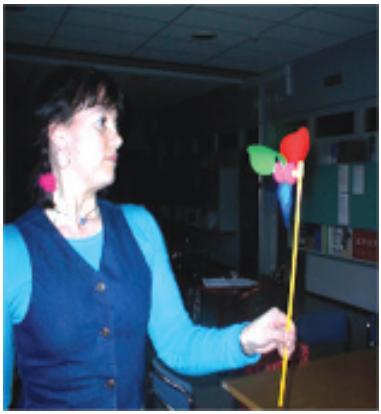
One can also color the water by rinsing the black board sponge in the water (the chalk colors the water milky white).

If one wants to get the beam visible in air, one needs smoke. If one makes a tube of paper a few wraps thick and makes fire in one end and then extinguishes the fire by blowing, the paper usually creates lots of smoke.

3. Let a beam of white light refract in a prism. Catch the beam on a paper behind the prism. What do you notice? Have you seen the same phenomenon somewhere? Can you explain how the rainbow arises?

   White light is light that comes from a glowing wire. One can use the light from an overhead or slide projector or a flashlight. It is important to screen the beam so that a narrow ray is achieved. On the overhead it is easy to put a thick paper on the glass and leave a slit free.

   The students should already have some conception about refraction of light. But how many can imagine that a spectrum will turn out? Then we get a ribbon of colors instead of a light band. When we move the white paper further away, we notice how the spectrum becomes wider and wider. Why? White light contains all colors. This can also be shown with a ”First of May spinning wheel” (see picture). Allow the students to make their own conclusions. If they miss something, it does not matter.



4. Take a convex lens and very thin silc paper. Try to get the paper to burn. The concave lens also has a burning point. Can this be seen? Can it be used to get paper to burn?

   This experiment can be done out-of-doors on a sunny day. It is also successful indoors with help of a projector lamp as source of light.

5. Lenses can be used to create pictures. In the eye there is a lens. How does the picture of something one is looking at arise? What is the use of spectacles?

   Give the students a lamp, a magnifying glass and a white paper. Let them try to find a picture of the light bulb on the paper by allowing the light to come together with the help of the magnifying glass. It is quite possible to see the picture of the hot-wire in the bulb on the paper. If they are successful they can also try to obtain an enlarged, respectively a diminished picture.

   The use of spectacles can be investigated with the help of two lenses, whereas one should represent the lens in the eye and the other one represents the lens in the spectacles.

Homework:
Reflect over at least three different light phenomena in your surroundings. Can you explain them?

To deepen the understanding:
Starting with the phenomena the students have found in their surroundings some experiments can be repeated and discussed. The shared knowledge of the class about these phenomena is gathered. A visit to an astronomic observatory might be interesting. Maybe there is time to do a project work over the sun system.

Material to deepen the understanding of the teacher:
Nordlab-Sverige, Göteborgs univ. http://www.fysik.org/didaktik/fysikdidaktik/fysikdid5.asp Nordiskt resurscentrum: http://www.fysik.org/elevexperiment/förstoringsglaset.pdf

Science of heat. Change of volume of water and air.

Read what has to be done, perform your experiment, and write down your observations.

1. Material: A balloon. Jars of glass with lids of metal.
   a) Blow air into the balloon. Close it with a firm knot. Put it into the freezer. What happens?
   b) Take six small empty glass jars with metal lids. Warm three lids. Fasten all lids equally hard. Allow a friend to open the jars after a while, when all lids feel equally warm. Is it possible to decide which jars had got the warm lids? Repeat the experiments a few times.
2. Material: A glass bottle, a funnel, a kettle, an electric hot-plate, cold water. Fill the glass bottle completely to the brim with cold water. Pour the water into the kettle and heat it until boiling. Pour the hot water into the bottle. If you use a funnel, take care that the funnel is not at all in the bottle. Use a stand for the funnel.
3. Material: An empty water bottle of thin plastic with cork, cold and warm water from the tap. Fill the bottle with hot water so that it becomes quite warm. Pour out the water. Close the bottle properly. Put the empty bottle under the cold water tap. What happens? Then try to warm it under the hot water tap.

Teacher's guide:

Goal: What happens when something is heated? Heat expansion. States of aggregation.

Discussion in the class before experiments:
Concepts: Air, water, heat, metal, (glass, plastic).
Discuss the concepts with the pupils before the experiments. It is enough to collect the pupils' everyday knowledge and make it the common knowledge of the class. The pupils can also in groups gather information about the concepts and thereupon compare with the results of the other groups (=brainstorming).
– One should also discuss measurements of temperature and in which ways heating can take place. What is common for the different methods?

Experiments:
If possible the pupils should work in groups. It is important that they make notes about how successful the accomplishment was and what they thought and reflected on. It is important to look back when the experiment is done and think about what could have been done better. What conclusions can be drawn? Do the results help us to understand also other phenomena in a better way?

1. Material: A balloon. Jars of glass with lids of metal.
   a) Blow air into the balloon. Close it with a firm knot. Put it into the freezer. What happens?
   b) Take six small empty glass jars with metal lids. Warm three lids. Fasten all lids equally hard. Allow a friend to open the jars after a while, when all lids feel equally warm. Is it possible to decide which jars had got the warm lids? Repeat the experiments a few times.

What happens with the air in the balloon? Which material is changing most when we investigate the jars with metal lids?

The next experiment can make the heat expansion concept more clear:

Material: Metal ball, "table" with a hole having the same diameter as the ball, gas heater, cold water.

Try whether the ball goes through the hole at different temperatures.

This experiment should be performed by the teacher! If the metal ball and the table are of two different metals, the heat expansion of these can be compared. Then the cold water is not needed.

2. Material: A glass bottle, a funnel, a kettle, an electric hot-plate, cold water. Fill the glass bottle completely to the brim with cold water. Pour the water into the kettle and heat it until boiling. Pour the hot water into the bottle. If you use a funnel, take care that the funnel is not at all in the bottle. Use a stand for the funnel.

A variant of the same experiment, where the electric hot-plate is not needed:

Material: A glass bottle, a cork with a transparent tube that passes through the cork, warm and cold water.

Fill the bottle completely with cold water. Heat the bottle under the hot water tap.

A rubber cork as used for juice bottles can be used. A transparent pipe of plastic can easily be thrust through it. If wished one can color the water with Indian ink pens, then it is easily seen how the water rises in the pipe. The experiment can be performed both in groups, if there are enough water taps in the class room, and as a demonstration performed by the teacher.

3. Material: An empty water bottle of thin plastic with cork, cold and warm water from the tap. Fill the bottle with hot water so that it becomes quite warm. Pour out the water. Close the bottle properly. Put the empty bottle under the cold water tap. What happens? Then try to warm it under the hot water tap.

It is okay to use a 1,5 liters Coca-Cola bottle. It might be fun to let the cold, buckled bottle stand on the teacher's desk, when going on with the lesson. Suddenly a pop is heard, when the bottle resumes its normal shape.

Homework:
For example: 1) Reflect over why the water kettle starts to whistle, when the water boils. What is there in the bubbles in boiling water? Why are water pipes cracking in cold winters? Why is there no ice at the bottoms of our lakes? 2) Why is a warm air balloon rising? 3) The iron balks in bridges are never joined together, a small split is left. Why?

To deepen the knowledge:
A subject teacher or some other expert on heat sciences can discuss with the pupils and focus their attention on important problems. The class teacher can let the pupils make projects from different regions of the heat sciences. Excursions to heat plants, water plants and other suitable plants can advance the projects. The projects should be assessed.

Some problems should be left open. The teacher should also point out that in natural sciences one will never get final results. A continuing progress takes place, people learn more and understand better all the time.

Material for the teacher:
Nordlab-Sverige, http://www.fysik.org/didaktik/fysikdidaktik/fysikdid5.asp, Värmelära. Fysikresurscentret, Lunds universitet http://www.fysik.org/.

Chemistry

Methods of separation

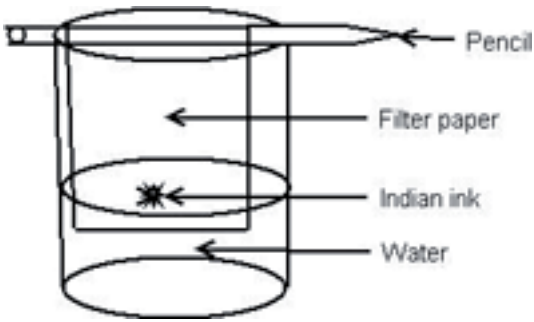
Read what you have to do , find and get the material you will need, do the laboration, make notes of all your observations.

Experiment 1, evaporation:

Material:
Salt
Water
Beaker
A low basin

Dissolve 1 teaspoon salt in 1deciliter water (one half of a normal drinking-glass). When the salt has dissolved you pour the solution in the basin and put it to stand on the windowsill for a few days. Note down what you think will happen. After a few days you can take your note pad and write down what you can see. What actually happened?

Experiment 2, paper chromatography:



Material:
Filter paper
A beaker with water
Indian ink dissolvable in water

How to do:
Cut a 2 cm broad strip from the filter paper. The strip should be a bit longer than the height of the beaker. Make a point with the Indian ink about 2 cm from the lower edge of the strip. Pour water until a height of 1 cm from the bottom. Fold the filter paper at the upper edge over the pencil that lays over the beaker's opening.

Please, observe that the Indian ink dot may not touch the water. After a moment what can you observe? Does Indian ink of different colors behave differently? Stop the experiment when the Indian ink has moved 4-5 cm up along the paper. Let the paper dry and glue it into your logbook.

Teachers' guide:

Goal:
The student shall understand what the concept "separation of substances" means and know such methods of separation as filtering, sedimentation and evaporation.
By doing experiments the student should learn to know methods of separation of substances from mixtures and solutions.

Discussion in the class prior to laboratory work:
Which different ways do you know to separate substances from each other?
There are different sorts of mixtures (solid matter in liquid or in another solid matter) and solutions (liquid dissolved in another liquid or solid matter dissolved in liquid)
Our waste water is cleaned through sedimentation and filtering, whereupon biologic and chemical cleaning takes place.

Laboratory work:
If possible the students should work in groups. It is important that the students make notes about how they carry out their task and about their observations!

Experiment 1, evaporation:

Material:
Salt
Water
Beaker
A low basin

Dissolve 1 teaspoon salt in 1deciliter water in a drinking-glass. When the salt has dissolved you pour the solution in the basin and put it to stand on the windowsill for a few days. Note down what you think will happen. After a few days you can take your note pad and write down what you can see. What actually happened?

How to do:
Dissolve 1 teaspoon salt in 1deciliter water (one half of a normal drinking-glass). Pour some of the solution in a low basin and put it to stand on the windowsill. A few days later the water has evaporated and we have salt left in the basin.

Suggestion for further experiments:

Filtering and evaporation:

Material:
Sand, salt, water, filter paper, 2 glasses and a funnel.

How to do:
Mix sand, salt and water in a glass. You get dirty, salty water.
Sedimentate: Let the mixture stand for a while. Most of the solid particles sink to the bottom of the glass. Thereupon the mixture is filtered; it is poured through a filter paper. The filtrate is gathered in the second glass. What do we have on the filter paper? What substance is the filtrate?
Evaporate: The filtrate consists of salty water. We can evaporate the water on a heater or use the method from experiment 1 above.

Separation of solid matters:

Material:
Iron filings, sand and a magnet.
Sawdust, sand and water.

How to do:

- Mix a teaspoon of iron filings and some sand. Bring the magnet (that should be wrapped in cling film, otherwise it will be difficult to get the magnet clean from iron filings again) near to the mixture (the iron filings attach themselves to the magnet).
- Mix sawdust and sand. Add water (the sawdust swims on the surface, the sand sinks to the bottom).

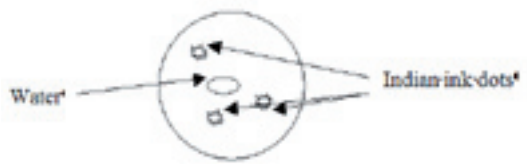
Experiment 2, paper chromatography:

Material:
Filter paper
A beaker with water
Indian ink dissolvable in water

How to do:
Cut a 2 cm broad strip from the filter paper. The strip should be a bit longer than the height of the beaker. Make a point with the Indian ink about 2 cm from the lower edge of the strip. Pour water until a height of 1 cm from the bottom. Fold the filter paper at the upper edge over the pencil that lays over the beaker's opening.

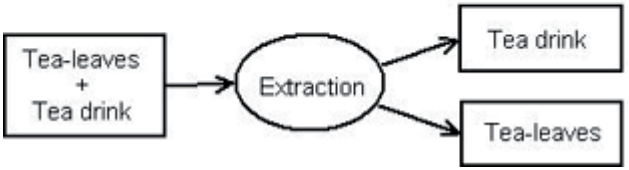
Please, observe that the Indian ink dot may not touch the water. After a moment what can you observe? Does Indian ink of different colors behave differently? Stop the experiment when the Indian ink has moved 4-5 cm up along the paper. Let the paper dry and glue it into your logbook.

Some other suggestions:
A white tricot cloth is tightened over a glass. Put patches of different colored Indian ink on the cloth. Drop some water in the middle of the cloth. We get nice color patterns.



One can also choose an Indian ink that is not dissolvable in water in order to show the difference.

When we prepare tea we dip the tea bag in hot water. The smell of the tea-leaves, their taste and color is brought over to the water. This is called extraction.



We use a solvent to dissolve a matter from another matter. At the same time we filter the tea-leaves using the tea bag as filter. Please, compare to making coffee.

Acidity

Read what should be done, perform your task, write down your observations.

Material:
Juice from red cabbage
Two beakers of clear glass or plastic
Vinegar and laundry soap

Experiment:

Pour some red cabbage juice in a beaker. What color is the juice? Add a few drops of vinegar. What happens? Why?

Pour some red cabbage juice in another beaker, add some drops of laundry soap. Observe! Note the change of color. What is the difference between vinegar and laundry soap? What happens if you slowly add drops of vinegar to the glass with laundry soap and red cabbage juice? Do you have a hypothesis?

What name can you give to the red cabbage juice?

Are there other ways to find out acidity than with red cabbage juice?

Can you think of something that it is necessary to control the acidity of in every day situations?

Teachers' guide:

Goal:

The student shall understand the concept acidity.

- Realize that sour-sweet-salt is different in meaning from acid-neutral-alkaline.
- Make experiments and realize that one visually can see changes in pH as changes in color.
- Learn central terms and concepts like e.g. indicator and neutralizing.
- Know that acidity is measured with pH and learn about the pH scale.

Discussion in the class before the laboratory work:

Discuss the concepts acid and alkaline.
Many of our every day products contain acids: berries, fruits, rhubarbs, when milk becomes sour milk acid is developing.
The opposite to an acid is called alkaline. Alkaline matter is for example ash and chalk stone. Our cleaning agents, soap and laundry soap are often alkaline.
Laboratory work:
If it is possible the experiments should be performed in groups. It is important that the students make notes about performance and observations.

Material:
Red cabbage juice. Cut pieces of red cabbage in a basin; pour on hot water from the hot water tap and let it stand a while to extract properly, or boil the mixture. Then you strain the mixture through for example a coffee filter. If you make so much juice that some is left over, you can freeze it and use it later.
Three clear glasses or plastic beakers per group.
For example vinegar, lemons, oranges or something else that you know is acid.
For example laundry soap (pH around 9) or baking soda.

Experiment:
Pour red cabbage juice in two glasses. Which color does the juice have? Add some acid into one glass. What happens? Then add some alkaline to the second glass. Make observations.

During the following discussion we talk about that matter changes color when an acid or an alkaline is added. Such matter is called indicator.

Is it possible to get back the original color?

Pour some acid in a glass and some water in another (neutral solution). Add some drops of indicator to both glasses. The glass with water works as a reference for a neutral solution. Neutralize the acid by adding some alkaline, a bit in a while, until the solution has got the same color as the reference solution.

It is also possible to measure the amount of acidity with a pH paper. On the pH paper box there is a color scale and values for different color nuance.

By dropping an alkaline, neutral and acid solution on the pH paper we learn the pH scale and the different values for an acid and an alkaline.

Acid matter has pH 1-6, neutral matter pH=7, alkaline matter ph 8-14.

This experiment can also be performed as teacher's demonstration.

Hints:

1. You can also use tea, blueberry juice or common beet (procedure as with red cabbage) as indicators.
2. We can with a sugar solution show that the concept sweet as opposite to sour is not valid.
3. We can compare the acidity of lemon and orange by neutralizing the same amount of both juices, so that an alkaline is added drop by drop and counts how many more drops has to be added to the lemon juice as compared to the orange juice.

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