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Abstract

Our world has changed fundamentally. To be successful today, not only universal knowledge is needed. More than ever, one has to have the ability and willingness for lifelong learning, continually responding to new developments and comprehending the world beyond our own horizons. Being capable of examining and coping with new and exciting challenges in a cooperative manner is one of the keys to success. Students, as future citizens, will be required to make decisions about technological and industrial issues. Hence, the school should afford the convenient learning environment for students, in order that they can develop skills, that enable them as adults solve emerged problems and to make decisions related to their everyday life. Therefore, students should *become lifelong learners.*

Moreover, students must not only become life long learners, but must be able to judge science as a human enterprise. This objective also positioned in a meta-level, just as lifelong learning is. Therefore understanding of the nature of science has been an objective of science since the first decade of this century. Reforms in science education curricula at least in the western countries emphasized the needs to prepare scientific literate students.

In Germany, according to PISA results (2000), only just over 3% of students are proficient at Level V (expert level) on the Scientific Literacy scale. More than one-quarter of 15-year-olds perform at Level I (elementary level) on the PISA scale. They have reached only an elementary level of scientific literacy and are capable only of reproducing simple factual knowledge and using everyday knowledge to draw and evaluate conclusion.

To rectify the present situation, many educational bodies proposed that history and philosophy of science (HPS) should be integrated in science curriculum to enhance students' scientific literacy. Some of the reasons are the following:

1- History of science promotes the better comprehension of scientific concepts and methods.
2- History contributes in connecting topics, in particular the disciplines of science with each other (Mathematics, Philosophy, Literature, Technology…) and in displaying the interface of science and culture (Arts, Ethics, Religion, Politics…) more broadly. History displays the integrative and interdependent nature of human achievements.
3- By examing the life and timed of individual scientists, history humanizes the subject matter of science, making it less abstract and more engaging for students.

These reasonings motivate the actual student-centered approach of this thesis, which emphasizes on reflecting on the self-learning process and this was realized by letting students designing activities, some of them were related to natural phenomena taken from the work of Alexander von Humboldt, the charismatic German adventurer who, from 1799 to 1804, conducted with the French Botanic Aim? Bonpland the first extensive scientific exploration of Latin America, in a arduous 6,000-mile journey and with his paradigm-changing discoveries he changed the way we see the world: Humboldt and Bonpland introduced systematically measuring in the scientific expedition.

The main research aim of this Ph-D thesis is to develop students' understanding of the nature of science on the background of Alexander von Humboldt's legacy for Grade 5 and Grade 6 classrooms in Baden-Württemberg schools.

The Ph-D research questions are:

1. What conceptions do students of the age group 10-12 regarding the nature of science hold?
2. Does students' understanding of science change as a result of discovery-based science activities taken from Alexander von Humboldt' scientific observations during his expedition to Latin America between 1799-1804? If yes, in what way?

This was done by:

1. Gathering background information about students' images of scientists and how they work.
2. Designing the most appropriate learning environment for improving their understanding of science.

At the beginning of the intervention study, Humboldt's life was used as a stimulus of student's thoughts about science at. Students were put in the same situation of a scientist: posing a question about a theme of their interest, designing and realizing an experiment in order to satisfy their curiosity. By doing so, students' understandings of the construction of scientific knowledge would be improved.

After a preliminary study between June and July 2002 at the Bammental Gymnasium, a case study took place from March till July 2003 at the Realschule Linkenheim for students of Grade 5.

Data from the pre-and post- questionnaires in the preliminary study showed that students learnt about factual knowledge irrelevant to their daily lives. Moreover, these students' main interests were about natural catastrophes. One of the outcomes of this study is that students liked to make authentic measurements in the nature and most of all; they wanted to learn about science while having fun.

Students' epistemologies about science and scientists at the Realschule Linkenheim were collected by using the current trends in science education research: pre- and post-questionnaires, classroom observation, pre- and post-interviews, the Draw-A-Scientist-Task and portfolio work. This intervention study was realized in 26 school sessions and all the work sessions were also video taped. Students' views about their actual nature of science aspects were characterized and coded using a framework drawing on the following areas: characteristics of scientists, history of science and the epistemology about science and scientists. Finally, students were asked to write about their learning process by using portfolios.

So, what conceptions students of the age group 10-12 regarding the nature of science held? The most important answers to this question were:

1. Students have already the stereotype image of a male scientist at work, like many students of this age in the western countries.
2. Students believed that scientists are most of the time working with chemicals, to generate new knowledge.
3. Unlike in the western countries such as the USA and Britain, students do not held the image of the crazy scientist.

Does students' understanding of science change as a result of discovery-based science activities taken from Alexander von Humboldt' scientific observations during his expedition to Latin America between 1799-1804? If yes, in what way?

There are two byproducts of my research, however:
Although students were not used to be independent learners and accordingly their portfolios showed that they are not used to reflect on their learning strategy, the teaching setting offered to students the opportunity for individual projects and for realizing them independently and for documenting their work. This means: my teaching and learning arrangement was successful in the sense of the school curriculum. At the end of the teaching setting, the positive changes in the class were: motivation, self-initiative, endurance. Students had the feeling to have created something together and are proud of their achievements, attitude/work tenancy and self-discipline. This also is a token of successful teaching and learning in the sense of the school curriculum.

As a remarkable consequence of the teaching setting was the positive acceptance of science by *girls* and their involvement in realizing technical works. It turned out, that in this age group students are already interested in the historical development of science and scientific discoveries.

The second byproduct concerns the qualification of the teaching & learning arrangement as a sample of "Lehrkunstdidaktik"

As to the recommendations: This study suggests that in order to develop some aspects of the nature of science, students need a free space at school to realize hands-on inquiry and a trained teacher who can translate to his students besides content knowledge, the nature of knowledge, the historical evolution of scientific knowledge and an understanding of how humans learn in diverse and complex ways.

Zusammenfassung

Unsere Welt hat sich grundlegend gewandelt. Um heute erfolgreich zu sein, braucht man nicht nur vielseitige Kenntnisse. Mehr denn je muss jeder die Fähigkeit haben, lebenslang neues Wissen zu suchen, auf Entwicklungen zu reagieren und die Welt über die Grenzen des eigenen Landes hinaus nur räumlich oder auch geistige Horizonte zu kennen und zu verstehen. Erfolgreich ist nur der, der sich selbstkritisch mit immer neuen Problemen auseinandersetzen, Ursachen, Regeln und Lösungen finden und sie in Zusammenarbeit mit anderen bewältigen kann.
Die Schüler als zukünftige Bürger werden angefordert, Entscheidungen über die technologischen und industriellen Aufgaben zu treffen. Folglich sollte die Schule ein Klima für Schüler anbieten, so dass sie Fähigkeiten entwickeln können, die ihnen in ihrem späteren Erwachsenenleben helfen, Probleme zu lösen und Entscheidungen zu treffen, die Bezug zu ihrem Alltag haben. Folglich sollten Schüler *lernen, wie man lebenslang lernt*.
Außerdem ist das Verstehen der Natur der Naturwissenschaften eine Zielsetzung der Naturwissenschaften seit der ersten Dekade dieses Jahrhunderts gewesen. Die Reformen naturwissenschaftlichen Curricula haben zumindest in den westlichen Ländern die Notwendigkeiten deutlich gemacht, „wissenschaftlich" gebildete Schüler anzustreben.

Nach der PISA- Studie (2000) erreichen in Deutschland nur wenig mehr als 3 Prozent der Schülerinnen und Schüler ein naturwissenschaftliches Verständnis auf hohem Niveau (Kompetenzstufe V). Über ein Viertel der Jugendlichen befindet sich auf dem unteren Niveau einer nominellen naturwissenschaftlichen Grundbildung (Kompetenzstufe I), die es ihnen lediglich erlaubt, einfaches Faktenwissen wiederzugeben und unter Verwendung von Alltagswissen Schlussfolgerungen zu ziehen und zu beurteilen.

Um die derzeitige Situation zu korrigieren, schlugen viele führende Fachdidaktiker vor, dass Geschichte und Philosophie der Naturwissenschaft im naturwissenschaftlichem Lehrplan integriert werden sollten, um das wissenschaftliche Bildungsniveau der Schüler zu erhöhen. Einige der Gründe sind die folgenden:

1. Es wird angenommen, dass die Behandlung der Geschichte der Naturwissenschaften das bessere Erfassen der wissenschaftlichen Konzepte und der Methoden fördert.
2. Betrachtet man die Geschichte der Naturwissenschaften, insbesondere die der unterschiedlichen Disziplinen der Naturwissenschaften (Mathematik, Philosophie, Literatur, Technologie...) und zeigt ihre Verbindungen zu den Kulturwissenschaften (Kunst, Ethik, Religion, Politik...), so macht dies die integrative und verbindende Kraft menschlicher Errungenschaften deutlich.
3. Indem man das Leben und die Zeit von einzelnen Naturwissenschaftlern erforscht, vermenschlicht die Geschichte der Naturwissenschaften und lässt sie weniger abstrakt erscheinen und ist somit motivierender für Schüler. Sie macht sie weniger abstrakt und mehr engagierend für Schüler. Diese Gedankengänge motivieren zu einem schülerzentrierten Ansatz, der das Nachdenken / Reflektieren über die Selbstlernprozesse hervorhebt. Dieser wurde verwirklicht, indem die Schüler Fragestellungen und das Design für Experimente zu deren Lösung selbst entwickelten und durchführten.

Einige der Fragestellungen hängen mit den beobachteten Naturphänomenen aus der Arbeit Alexander von Humboldts zusammen. Er war ein charismatischer deutscher Abenteurer, der von 1799 bis 1804, mit dem französischen Botaniker Aimé Bonpland die erste umfangreiche naturwissenschaftliche Erforschung in Lateinamerika durchführte. In

einer beschwerlichen legendären Reise von 6000 Meilen und mit seinen paradigmaveränderten Entdeckungen änderte er die Weise, wie wir die Welt sehen: Humboldt und Bonpland setzten in der naturwissenschaftlichen Expedition erstmals systematisch das Messen ein.

Das Hauptziel dieser Dissertation ist es, das Verständnis der Schüler über die Natur der Naturwissenschaften im Kontext Alexander von Humboldts Vermächtnisses für die Klassenstufen 5 und 6 an Schulen in Baden-Württemberg zu entwickeln. Die Forschungsfragen der Dissertation sind:

1. Welche Konzeptionen haben Schüler der Altersgruppe 10-12 über die Natur der Naturwissenschaften?
2. Wird das Naturwissenschaftsverständnis der Schüler verändert aufgrund entdeckungsorientierten naturwissenschaftlichen Tätigkeiten, wie sie von Alexander von Humboldt als naturwissenschaftliche Beobachtungen während seiner Expedition nach Lateinamerika zwischen 1799-1804 gemacht wurde? Wenn ja, in welcher Weise?

Das Vorgehen in der Arbeit war wie folgt:

1. Sammeln von Hintergrundinformationen über Vorstellungen der Schüler über Wissenschaftler und wie sie arbeiten.
2. Konzipierung einer angemessenen Lernumgebung mit dem Ziel, ihr Verständnis von Wissenschaft zu verbessern. Zur Einführung der Interventionsstudie wurde das Leben Humboldts als Anregung für die Schüler dargeboten, sich Gedanken über Naturwissenschaft zu machen. Die Schüler wurden in die Situation eines Wissenschaftlers versetzt: Eine Fragestellung über ein Thema ihres Interesses finden, ein Experiment entwerfen und verwirklichen, um ihre Neugier zu stillen.

Im Anschluss an eine Pilotstudie zwischen Juni und Juli 2002 am Bammentaler Gymnasium, wurde eine Fallstudie von März bis Juli 2003 an der Realschule Linkenheim für Schüler der Klasse 5 durchgeführt. Die Daten der Vor- und Nachtest-Fragebögen in der Pilotstudie zeigten, dass die von den Schülern erworbene Sachkenntnis für ihr tägliches Leben bedeutungslos sind. Das Hauptinteresse dieser Schüler bezog sich auf Naturkatastrophen. Ein Ergebnis dieser Studie ist, dass Schüler authentisches Messen in der Natur durchführen wollten; am wichtigsten war ihnen jedoch, Naturwissenschaft mit Spaß zu erlernen.

Die Vorstellung der Schüler über Naturwissenschaft und Wissenschaftler wurde bei Realschülern in Linkenheim erhoben, indem die aktuellen Instrumente der Bildungsforschung verwendet wurden: Fragebögen, Teilnehmende Beobachtung, Interviews, und Portfolios. Die Interventionstudie wurde in 26 Schulstunden verwirklicht, alle Projektstunden wurden mit Video aufgezeichnet.

Folgende Ergebnisse wurden in Linkenheim erhoben:

1. Die Schüler haben das selbe stereotype Bild eines männlichen Wissenschaftlers bei der Arbeit, wie viele Schüler dieses Alters in anderen westlichen Ländern.
2. Die Schüler glauben, dass Wissenschaftler die meiste Zeit mit Chemikalien arbeiten, um zu neuen Erkenntnissen zu gelangen.
3. Anders als in den westlichen Ländern wie den USA und Großbritannien hatten die Schüler nicht die Vorstellung des „verrückten Wissenschaftlers“.
4. Die Schüler waren nicht gewöhnt, selbst gesteuert zu arbeiten, und ihre Portfolios zeigen, dass sie nicht gewöhnt waren, über ihre Lernstrategie zu reflektieren.

5. Das Lehrarrangement bot den Schülern die Gelegenheit, einzelne Projekte zu verwirklichen, sie selbstständig durchzuführen und die Ergebnisse ihrer Arbeit im Portfolio zu dokumentieren.
6. Am Ende des Projekts gab es positive Veränderungen in der Klasse bei:
   Motivation, Eigeninitiative, Durchhaltevermögen. Die Schülerinnen bzw. Schüler hatten das Gefühl, etwas gemeinsam geschafft zu haben und waren stolz auf ihre Leistungen, Einstellung/Arbeitshaltung und Selbstdisziplin.
7. Ein bemerkenswertes Ergebnis des Projekts war es, dass Mädchen und Jungen Naturwissenschaften gleichermaßen attraktiv fanden, und gleichermaßen in die Verwirklichung der praktischen Laborarbeiten einbezogen werden konnten.
8. In dieser Alterstufe sind die Schüler bereits an der historischen Entwicklung der Naturwissenschaften und der naturwissenschaftlichen Entdeckungen interessiert.

Diese Studie empfiehlt, dass, um einen Eindruck von der Natur der Naturwissenschaften bei den Schülern zu entwickeln, sie mit ergebnisoffenen Fragestellungen konfrontiert werden sollten, die Raum für selbst entwickelte Experimente bieten.
Dies erfordert Lehrkräfte, die über die Vermittlung von Fachwissen hinaus, einen Entdeckungszusammenhang hin zur Natur der Wissenschaften, ihrer historischen Dimension und dem Verstehen des eignene Lernens eröffnen.

Chapter 1

Introduction, statement of the problem and limitations

Introduction

Science is one of the greatest achievements of human culture and has directly or indirectly transformed both the social and natural worlds. Human and environmental problems requiring scientific understanding are pressing. Ethical questions arise increasingly in the science classroom. The Greenhouse effect, species' extinction, water, air and land pollution, global climate change, genetic engineering and so on, as well as historical, philosophical and cultural issues, are all matters raised by students and appear in new science curricula.

Novak (1963) emphasized that science classes should teach science; not isolated facts, not history of technology, but an understanding of the major ideas of science and the process by which these ideas are advanced.

For instance, the national curriculum of England and Wales, implemented in September 1989, was framed by 17 attainment targets (Jenkins, 1990). In attainment target 17, *the nature of science*, requires that:

> *"Pupils should develop their knowledge and understanding of the ways in which scientific ideas change through time and how the nature of these ideas and the uses to which they are put are affected by the social, moral, spiritual, and cultural contexts in which they are developed; in doing so, they should begin to recognize that while science is an important way of thinking about experience, it is not the only way" (DES and Welsh Office, 1989).*

In Denmark the upper secondary science education had undergone a major reform starting 1988 after a research carried out by Nielsen and Thomsen (1990) and it has shown that students in Denmark find physics to be difficult, unrelated to other school subjects, and with little connection to real life (Nielsen and Thomsen, 1985-88, cited in their article 1990). The proposed reform was to get away from the earlier *science centered* teaching of physics, towards a presentation of physics as *a human activity*. Among the five dimensions that aim at persuading the students of the fact that physics has been – and still is – an important and indispensable part of our culture at large was history and philosophy of science.

Finally, the school, a part of the society, is the best place where students can learn about environmental and social-related issues and to be aware of their impacts on individuals and nature. It is well known too, that students can develop both cognitive and affective skills during the learning process, which enable students to come to hold themselves their own reasoned opinions on the subject.

1 Problems of science literacy in the curriculum

Sjøberg (2001) wrote in a paper presented to the Third International Conference of ESERA in Thessaloniki, Greece, that in March 2000, the EU ministers of Education and Research met in Sweden for the first joint meeting in 10 years, with only one item on the agenda: the problems related to the (lack of) interests in and (falling) recruitment to science and technology (S&T). Furthermore, in many occidental and advanced industrial countries, such as Japan, Germany and the United States, numerous studies stressed on this dislike of science by students. All this shows how much this problem is emerging and how it will have a serious impact on the future of these countries. This is why Science Litteracy (SL) and the Public Understanding of Science and Technology (PUST) take now a major priority in many surveys and studies, such as the AAAS, PISA, etc..

Sjøberg attempted to suggest a series of reasons for why we have this problematic situation: changes in Science and Technology and changes in society and the life-world of the young.

For many decades, studying science was high status and scientists enjoyed fame as well as increasing budgets. For instance, engineers were heroes; they were admired and praised by artists. They figured as the stars in novels and films. But in recent years, the situation has changed dramatically. Many countries experience a falling interest and a lack of recruitment in Science and Technology studies in schools. One may even talk of a growing distrust and falling prestige. The public image of engineers and scientists has changed. In the USA or England the present cartoon version is often the crazy or mad scientist – experimenting with bombs and poisonous gases, a destructive and cruel person. In recent American movies, the plot involves frequently the scientist, not as the hero but as the villain. Brilliant, but cold brains, devoid of ethical considerations, human feelings and empathy.

Science and Technology used to be seen by many as the *solver* of the problems – today Science and Technology is seen by many as the *creators* of the problems. Science has lost its attraction – technology has lost its innocence.

In the past, science used to be seen as being a pure and often disinterested academic search for truth- regardless of practical use. The researcher was often lonely in his lab, and the costs for apparatus were manageable by universities. Scientists were often perceived as radical thinkers, as antiauthoritarian rebels, as intellectual freedom fighters (Hobsbawm, 1995).

Some bright youngsters were attracted by this image of intellectual as well as social bravery. But present science is different from the academic one. Present science is given different names: Post-academic science (Ziman, 2000), Big Science, techno-science.

Research is no longer an individual testing of interesting ideas in the next-door lab. Research is now undertaken by big multinational companies or institutions or programs like CERN, NASA, or the Human Genome Project. They have Billion-Euro budgets, are based on international cooperation and involve thousands of researchers. Scientists and engineers often work for military, industry and large multinational companies. The Young, bright rebel of today is not attracted by science and technology the way the brightest brains were some decades ago.

Big Science is often seen as frightening. Some people react emotionally as well as intellectually when hearing about the *ambitions* of present science. For instance, *Biologists* used to be seen as nature-lovers. Now they are often perceived and portrayed in media as modern versions of Frankenstein, tinkering and manipulating with the deepest secrets of life. Some say they take it too easy on the ethics. Some fear they are crossing borders they should not cross. Critical voices come from conservative as well radical political stances.

Sjøberg advocated that by analyzing and not ignoring such attitudes and feelings, as well as the changes in Science and Technology and their role in society, they may be part of the key to understand and to address the situation of the current disenchantment, lack of trust and falling enrollment.

But there are also changes in the life-world of the young. According to Sjøberg, the young of today might be called *Homo Zappiens* – they zap from channel to channel. They live a life with remote control devices, celluphones and Internet.

There is much competition to gain the attention of the young. If they are not entertained, they zap to another channel. Media experts indicate that 8 seconds attention is the maximum they can count on.

Learning science may require concentration and hard work. Science and mathematics are not common sense. Science and mathematics require an intellectual effort that is sustained for more than 8 seconds at a time. In a world like this, science and math may be the losers.

The new heroes are many, among them sport heroes, movie stars and pop idols. Seventeen year-old school leavers who become football players may earn 10 or maybe 100 times that of a professor of science – or that of a minister of education. Other idols are the media people and journalists, people who become famous, people who live exciting lives. People who are visible in television. The perceived lives of a lab researcher do not appeal to the same extent.

Those who are attracted by easy money, also see that 25 year old stockbrokers and -advisors make millions – even when they give bad advice. Lack of scientific litteracy does not hold them back in their careers. In a world like this, scientists are not glamorous, and studies in mathematics cannot compete with trendy new subjects that are fun, promise easy success and require less intellectual effort.

A key aspect in the lives of young is the search for *meaning* and *relevance*. They like areas where their voice is taken seriously, where their views count. Science and mathematics have an image of authority, at least as school subjects. Answers are either right or wrong. There is no place for arguments and personal views. It is easy to demonstrate your ignorance in such subjects. The lack of personal *meaning* and the image of eternal truth and correct answers put off more young people today than before.

Finally, Sjøberg pointed that possible changes in science curricula, teacher training, pedagogies etc, may address the problems we are facing. This would be simply done by understanding the present situation in its social, political and cultural context.

Why engage in Public Understanding of Science and Technology (PUST)? A question raised and answered by Mathias (1999). In his article, the author stated that there are many rationales for engaging in PUST activities, whose challenge is to make science accessible to the public by providing them with information and facilitating their understanding of scientific facts, and thus deliver a better informed public. Three key points alerted this practitioner of PUST activities at the John Innes Center (JIC), Norwich:

1. Many people are prejudiced against their own ability to understand science and the ability of scientists to communicate science;
2. The majority of non-scientists have a very limited understanding of science; and
3. If science is not deliberately and clearly communicated, then no matter how good the science results, it and/or the particular contribution of a research organization will not be recognized.

He advocated that the public has the ability to understand and evaluate complex scientific information when that information is of direct importance in their lives, e.g., the risk/benefit analysis is involved in considering surgical/therapeutic procedures. Increased understanding of science, and the scientific process, does empower citizens, potentially enabling them to participate in debate and make consciencious decisions about the use and role of Science and Technology in society and their own lives.

The author also stated that in Britain, the government is currently championing the "democratization of science" and a general increase in scientific literacy that would facilitate the setting up, and maintenance, of a genuine democratic process. But what "democratization of science" really means and how it is to be achieved remains undefined. The intention is to bring the general public's opinion into the government's process of deciding which areas of science should be supported. And that there is a perception not restricted to scientists, that public anxiety arises from not understanding enough science. However, evidence shows that greater understanding does not necessarily result in greater acceptance. If anything, improved understanding causes people to be more skeptical when evaluating scientific issues. This is a positive benefit, as skepticism reduces the likelihood of the public being misled by inaccurate or misleading statements. It does, however, require that scientists are able to better explain scientific issues as they face a more articulate, better-informed and skeptical public.

Although some single issue groups pressure have attempted to pre-empt the government by assembling "citizen's juries" to provide "public opinion" on the lobby issues of interest to the pressure groups – with predictable results, such pressure groups see "democratization" as a potential route to progress their agendas, but also fear that informed public opinion may not support those objectives.

What is the unsaid role of PUST? To Mathias' opinion, the most important aspect, is that it should be a sharing of wonder. Most scientists are enthusiasts for, if not obsessive about, their science and fascinated by the insight it gives them into the world in which we live. Rather than the cold, calculating, manipulative scientist of popular media and imagination, many scientists have an intense sense of the beauty and wonder of the systems they study.

Unlike the past generations, who had more contact with nature, the modern child's introduction to science is more likely to be through computers. But even in this computer generation, few children pass through their childhood without a period in which they are fascinated by dinosaurs or pester their parents for keeping household pets.

Moreover, in a fast growing and depending society on Science and Technology, where a student knows sometimes more than his teacher about the modern devices, students are still taught science in the same traditional way. The demand is pressing and urging that teachers must be trained to respond to students' needs and interests (e.g., Aikenhead, 1992; Fullick, 1992).

2 Importance in teaching science using the History of science approach

To overcome this problem of science and technology illiteracy, at different times and places, there have been appeals for including a historical component in science programs. Some of the assumptions are the following:

4- History of science promotes a better comprehension of scientific concepts and methods.
5- History contributes in connecting topics, in particular the disciplines of science with each other (Mathematics, Philosophy, Litterature, Technology…) and in displaying the interconnections of science and culture (Arts, Ethics, Religion, Politics…) more broadly. History displays the integrative and interdependent nature of human achievements.

6- By examining the life and time of individual scientists, history humanizes the subject matter of science, making it less abstract and more engaging for students (Matthews 1994, p.8 and Buck, 1996).

Kuhn (1962) in the introduction of his book *the structure of scientific revolutions* wrote:

> *"History, if viewed as a repository for more than anecdote or chronology, could produce a decisive transformation in the image of science by which we are now possessed".*

In addition, Matthews quoting Mach said: "scientific theory can only be understood if its historical development is understood" (Matthews 1994, p.86). Furthermore, Irwin (1997) argued that the historical aspects of the subject could be used by students to dispel the myth of infallibility by scientists, as people with all the right answers and the impression of science as a dogma. Indeed, modern school science still suffer from the legacy of the traditional textbook portrayal of science as an objective, rational process with an unquestioned claim to authority and truth and where disagreement, conflict or doubt are rarely portrayed even though they have played an essential role in scientific progress.

Moreover, numerous government and educational bodies proposed recently that History and philosophy of Science and science education should be integrated. Among these has been the American Association for the Advancement of Science in two of its very influential reports *Project 2061* (AAAS 1989) and in the Liberal Art of Science (AAAS 1990); the British National Curriculum Council (NCC 1988); the Danish Science and Technology Curriculum, and in The Netherlands, the PLON curriculum materials (cited in Matthews, p. 5).

The AAAS has written:

> *Science courses should place science in its historical perspective. Liberally educated students-the science major and the non-major alike-should complete their science courses with an appreciation of science as part of an intellectual, social, and cultural tradition… Science courses must convey these aspects of science by stressing its ethical, social, economic, and political dimensions (AAAS 1989, p. 24).*

In the *International Handbook of Science Education* Matthews (1998) reported that in the past decade, there have been about 300 scholarly papers published on the subject of history, philosophy and science teaching. Remarkably, between 1988 and 1992, there were at least six special issues of academic journals devoted to the subject.

In addition, a special issue of Science & Education (Issue no. 9, (eds.) M. Matthews) appeared in 2000 and it was dedicated to research done in this field in Germany.

3 Incentive: the work of Alexander von Humboldt.

In Britain as early as the mid-nineteenth century, claims have been made to accommodate the history of science within school curricula. When the members of the British Association for the Advancement of Science met in Glasgow in 1855, they were told by their president, that what was wanted in the teaching in the young, was "not so much the mere results, as the *methods,* and above all, the history of science", if education were to be "well-conducted to the great ends in view". It was, as might be expected given the concern of the British

Association ultimately for the benefit of science itself. By learning to “better appreciate the labour of others”, students would be better prepared to recognize “the golden strands of truth in the midst of much error” (British Association, 1856 cited in Jenkins, 1990). A section entitled “Human Aspects of Science” of the 1917 of the same Association urged that there must be “more of the spirit and less and less of the valley of dry bones” in school science teaching and suggested that this might be achieved by teaching “lessons on the history of science”. History and biography, it was claimed, enabled a comprehensive view of science to be constructed “which could not be obtained by laboratory work” and they “supplied a solvent of that artificial barrier between literary studies and science” commonly found in schools (British Association, 1918).

Two main reasons among the AAAS recommendations for including history of science in the curriculum are:

> *“One reason is that generalizations about how the scientific enterprise operates would be empty without concrete examples… a second reason is that some episodes in the history of the scientific endeavor are of surpassing significance to our cultural heritage. Such episodes certainly include Galileo’s role in changing our perception of our place in the universe… Darwin’s long observations of the variety and relatedness of life forms that led to his postulating a mechanism for how they came about… These stories stand among the milestones of the development of all thought in Western civilization” (AAAS, 1994).*

Furthermore, because till in the 21st century the scientific research is still a human endeavor (Drouin, 2003), I recurred to Alexander von Humboldt as he who personified this adventure “à la perfection”. He appeared to me to be an ideal history model in designing activities and experiments related to science activities (Naturwissenschaftliches Arbeiten) and natural phenomena (Naturphänomene) for young teenagers, especially for those students in Grade 5 and Grade that were open to my teaching project, especially because of the implementation of the new curriculum in 2004. Humboldt, being one of the first popular scientists in the 19th century and Charles Darwin's mentor, was a naturalist, explorer, philosopher, writer, teacher, and a major figure in the classical period of physical geography and biogeography, areas of science now included in the earth sciences and ecology. With his book *Kosmos, Entwurf einer physischen Weltbeschreibung*, he made a valuable contribution to the popularization of science.

At school and in the elementary level, I heard in the Geography discipline for the first time about Alexander von Humboldt. It was a very nice coincidence that he crossed my life again and this time in his country! Moreover, one important factor played in my favor: Humboldt published almost all his work in French. In addition, history of science was always a passionate topic for me on one hand and I have finally the opportunity to develop my teaching vision by using this theme in order to enhance students’ understanding of the nature of science, the cornerstone of scientific literacy on the other hand. Hence I decided to go through.

How will be Alexander von Humboldt introduced in the classroom? Humboldt’s life will be used as a stimulus of the student’s thoughts about science at the beginning of implementation of the teaching. Students will be put in the same situation as Humboldt: going to the nature and facing the unknown with physical instruments. This trend in learning, asking students to make authentic measurements of natural phenomena in the nature, makes science more accessible to students. Unfortunately, this was not possible in my country. In fact, students had to learn content knowledge only in the classroom. This produced consequently their disinterest and dislike of science.

4 The objective: justifying my vision of teaching science in the knowledge based society

I believe in Dewey's philosophy about education. For him, knowledge and ideas emerged only from a situation in which learners had to draw them out of experiences that had meaning and importance to them (Dewey, 1916). Furthermore, Dewey divided the process of instruction in 5 phases:

1. Pupils have a genuine situation of experience-that there be a continuous activity in which he is interested.
2. A genuine problem develops within this situation as a stimulus to thought.
3. Pupils possess the information and make the observations needed to deal with.
4. Suggested solutions occur to him that they shall be responsible for developing in orderly way.
5. Pupils have opportunity and occasion to test their ideas by application, to make their meaning clear and to discover for themselves their validity.

As a science teacher with 8 years experience in my country, in different types of schools (technical institute, high school and academic middle school) and for different students' age groups (18-24, 15-17 and 14-16), I knew how much science is disliked by students, since they have to learn by rote scientific explanations and this limited their imaginations. But when they learnt about topics of their own interest or related to their everyday life, they were asking many questions and the disinterest disappeared. Students wanted to be involved actively in science by having the opportunity to present their ideas. As for my part, submerged by the content curriculum, that is taught most of the time with the frontal method, in order to cover the required science curriculum on time and paralyzed by the school laws that restricted my teaching vision, all I could afford for my students was an engaging atmosphere, where all questions are considered important and that learning science is also fun.

The curriculum makers in Baden-Württemberg (BW) for natural phenomena and science work topics have the purpose that science is exercised in a project as a whole, in such terms that students will work in groups, their curiosity will be aroused, and most of all, they will learn about science with *Freude*. Moreover, such activities will develop their observing skill, their creative mind, build their feeling of responsibility; they will be able to make their own judgments and decisions, and to find out by themselves solutions to environmental issues. Finally, these education activities will help pupils as future citizens to participate intelligently in making social and political decisions on matters involving science and technology.

Indeed, this policy is very consistent with my beliefs in teaching science: on one hand, presenting to students topics of their interests and related to their daily needs and on the other hand, providing them with a suitable learning environment, where students are asked to design by themselves their activities and to find answers to their questions, while having fun. All this would be done in a relaxed atmosphere.

For instance, these themes are mentioned in the new BW- curriculum for Naturphänomene in Grade 6 in the Gymnasium, implemented in the classroom since 2000: water, electricity and air, and of 5 optional units: heat, sound, light, weather and motion.

For the new subject "Naturwissenschaftlicher Arbeiten" (NWA) that comprises biology, chemistry and physics for Grade 5 in the Realschule, there are themes as wildlife, dealing with everyday substances, mysterious forces, plants live differently, understanding a biotope, we become adults, technique and nature, air, water, to experiment with sound and light, revealing micro- and macrocosmos with aid substances and from raw material to product. The new Realschule NWA- curriculum was tested since 2001 and will be implemented in 2004.

5 Research questions

The international large-scale comparative surveys such as PISA and TIMSS, who describe the levels of achievement of schoolchildren, are considered as the educational studies parallel or the so-called Big Science or techno-science. These shed the light on the alarming low science literacy and disenchantment of students with Science and Technology in the western countries. Furthermore, the International Centre for the Advancement of Scientific Literacy (ICASL), a research institute in the USA supported by the National Science Foundation (NSF), undertakes and publishes regularly surveys of public scientific litteracy, as well as of public attitudes to science and technology. The Center presents itself the following way:

> *Not more than 7 percent of Americans qualify as scientifically litterate by relatively lenient standards. Recognizing this serious problem, governments in most industrialized nations are making concerted efforts to address the issue of pervasive illiteracy.*

According to Sjøberg (2002), statistical data and most surveys, however, do not shed much light on the underlying causes of many of the present educational concerns; *why* have science and technology apparently lost their attraction for many young people, and *what* might be done to remedy this situation?

In addition, in *Science for all Americans* (American Association for Advancement of Science, 1989 and 1991), many international educational standards (for a detailed review, see McComas and Olson, 2000), as well as most educational studies in the domain of scientific literacy (e.g., Lederman et al), the meaning and importance of the nature of science are extensively described and stressed on the fact that the nature of science is a crucial component of science education programs and thus it is the key for promoting students' science literacy. In fact, research studies have been done since the 1960s to find the factors that affect and ways to improve student levels of understanding (such as Solomon et al, 1992; Lin, 2002; Heering, 2000). Indeed, science educators have reached a consensus that understanding of science is an important goal of science education (Lin et al, 2004). Unfortunately, Aikenhead and Ryan (1991) and Lederman (1992) found that students and teachers do not have enough understanding of the NOS. Note that according to these studies, using the history of science has been considered as an effective strategy.

Furthermore, as we live in a period of dramatic changes in the science education community, research results (e.g., *The National Science Education Standards*) recommend that science should be taught in the same way it is built - using inquiry. In scientific inquiries students are the ones who ask the question, devise ways to answer, collect and analyze data in the process of knowledge development, plan and present their findings and take into consideration constructive criticism (National Research Council, 1996).

Based on the above reasoning and the numerous literature review suggestions in this field, I have the strong belief that better scientific literate students would be attentive future citizens in issues related to decision-making, the points of departure of the present PhD thesis will be the following two questions:

3. What conceptions do students of the age group 10-12 regarding the nature of science hold?
4. Does students' understanding of science change as a result of discovery-based science activities taken from Alexander von Humboldt' scientific observations during his expedition to Latin America between 1799-1804? If yes, in what way?

This will be done by:

3. Gathering background information about students' images of scientists and how they work.
4. Designing the most appropriate learning environment for improving their understanding of science.

My study was implemented on 10 to 12 year olds in 2 classrooms, Grade 5 and Grade 6 in a Realschule and a Gymnasium respectively. A preliminary study took place between June and July 2002 at the Gymnasium and an intervention study took place from May till July 2003 at the Realschule. The outcomes of the study are thus limited to this sample and cannot be generalized to a larger sample, but it can give hints and ideas about what conceptions students do have regarding the nature of science and under what learning arrangement does their understanding of science change (in case there is a change).

6 Spin-off: my teaching & learning arrangement seen as a piece of 'Lehrkunstdidaktik'

At the end of my final teaching and learning arrangement in which I obtained the data relevant to the research questions mentioned in chapter 4 it turned out, that this teaching & learning arrangement might as well be regarded as a "Lehrkunstdidaktik-Stück". This term belongs to the didactics concept of Berg & Schulze (1995) where certain teaching & learning arrangements are seen as designed as a kind stage play, in which dramaturgic criteria play an important role and where the selection of the teaching & learning content of such a "play" must meet severe requirements ("Menschheitsthema"). I was invited by the University of Education at Liestal, Switzerland, to report on my teaching and learning design during the regularly held "Wagenschein Conference", where Lehrkunstdidaktik is in the centre of attention. Thus, this invitation can be taken as an acknowledgement of the teaching aspect of my thesis. Paragraph 30 will report hereabout in more detail.