Chapter 7

Implications and recommendations

Introduction

In this last chapter, my aim is to make a global overview of the outcomes results oft students' epistemologies about science and scientists derived from the 2 studies described in details in the previous chapter. Furthermore, I will present my teaching and learning arrangement using the framework of the history of science appropriate for 10-12 year-olds.

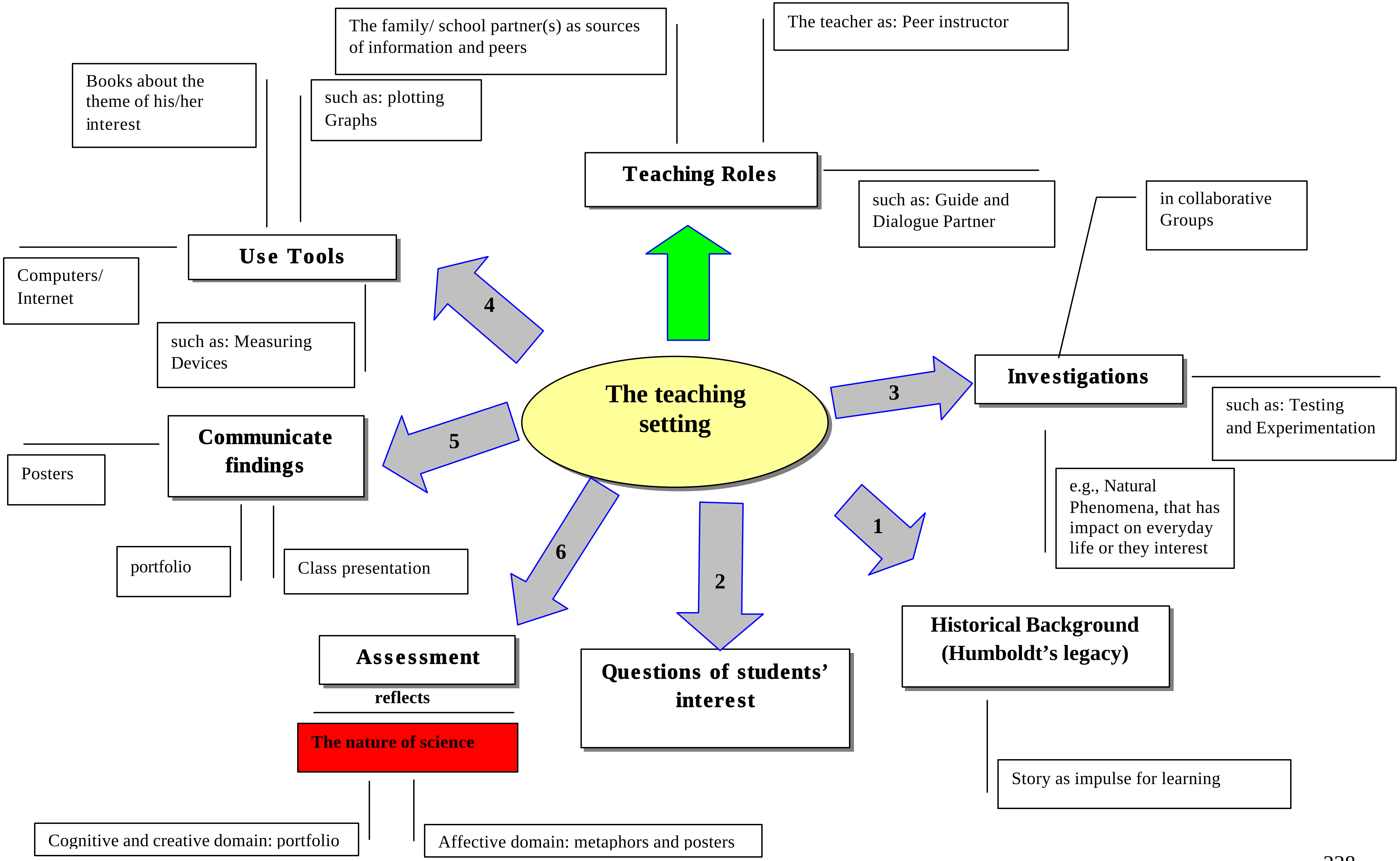
The research questions were:

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?

The preliminary study at Bammental Gymnasium, realized between June and July 2002, was exploratory by nature in order to get used to German students and the German school system on one hand, and to test the designed activities of Alexander von Humboldt with students on the other hand.

The main study at Linkenheim Realschule aimed to collect in-depth detailed information about students' epistemologies of science and scientists. Students' epistemologies about science and scientists 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.

The following schema 7 depicts a clear overview of the teaching setting concept realized in Grade 5 class between March and July 2003.



The family/ school partner(s) as sources of information and peers
The teacher as: Peer instructor
Books about the theme of his/her interest
such as: plotting Graphs
Teaching Roles
such as: Guide and Dialogue Partner
in collaborative Groups
Use Tools
Computers/ Internet
such as: Measuring Devices
4
3
Investigations
such as: Testing and Experimentation
The teaching setting
Communicate findings
5
Posters
e.g., Natural Phenomena, that has impact on everyday life or they interest
6
1
2
portfolio
Class presentation
Historical Background (Humboldt's legacy)
Assessment
reflects
Questions of students' interest
The nature of science
Story as impulse for learning
Cognitive and creative domain: portfolio
Affective domain: metaphors and posters

29 Discussion of results and implications.

Matthews (1998) believed that many science educators thought that inclusion of historical and philosophical aspects of science in the science curriculum can help to overcome a number of science education’s problems, such as lack of student motivation and learning, female non-participation, the two-cultures gap, public distaste or antipathy towards science, and inadequate of the place of science in history, culture and society (Matthews, 1998, p. 992). Because of its weirdness for students, the ‘nature of science’ had been given many adjectives by science educators as Panacea or Pandora’s Box (Heron, 1996 cited in Matthews, 1998, p. 991), and black box.

On the other hand, despite the appeals to insert the history of science in science education, these appeals were based solely on intuitive assumptions and anecdotal evidence (Abd-El-Khalick and Lederman, 2000). Additionally, the history of science was viewed as a repository for more than anecdote or chronology (Kuhn, 1962).

In the special issue of Science & Education on History and Philosophy in German science education, Riess (2000. p. 330) wrote that the knowledge of the German population about scientific results and methods is – seen on an absolute scale – only poor. Where the knowledge comes from is not clear, but school lessons seem to have less influence than every day experiences and popular information resources. There has been much less research on epistemological knowledge and attitudes. But it can be stated that, the image of science, of scientists and of the process of scientific findings which is transferred by school lessons, teacher training and in the media is insufficient and does not contribute to an adequate comprehension of the role of science and technology in society.

Gräber (2002) analysed the discussions that took place in 1998 in Kiel, Germany at the 2nd International IPN- Symposium of Scientific Literacy and he represented students’ competencies to be gained.

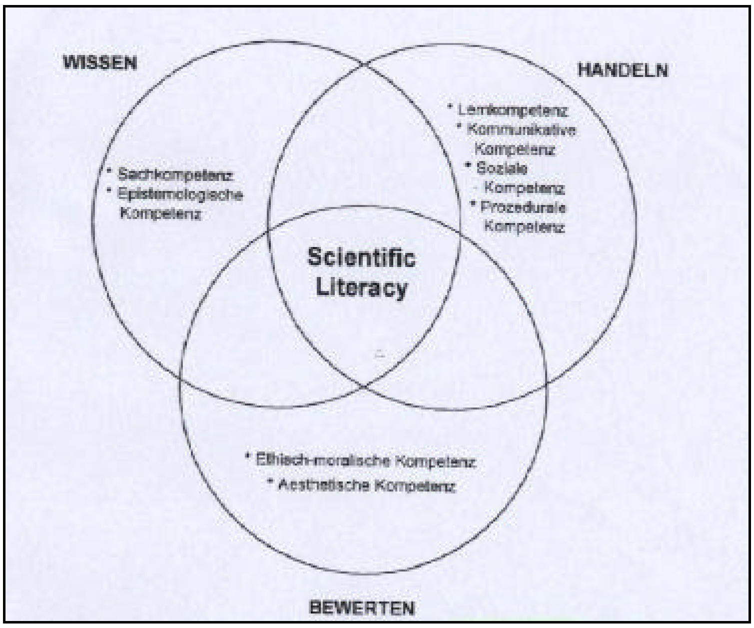


Figure 18: A proposal of lifelong competencies to be gained by students from the 2nd International IPN-symposium on scientific Literacy (SL). SL is the intersection of the 3 competencies: knowing, acting and assessing (Gräber, 2002, p. 137).

The approach of this study was to develop Scientific Literacy by students using a historical context. One of the objectives of the research questions was to collect students' epistemologies about science and scientists.

In the present research, although I had a small sample, I could obtain detailed views about German 10-12 year-olds students' images of science and scientists. Although, there has been researches in the Anglo-Saxons countries about developing informed views about the nature of science by using the history of science, but these researches had for samples, K-12 students, university students or students who are enrolled in teaching courses. Moreover, Anglo-Saxons education studies apart Solomon (1992, 1996) in Britain and Carey (1989) dealing with 10-13 year olds are seldom. In Germany, there is the research group of Riess at Oldenburg, who is tackling this subject but only for higher education university students.

Hence, the importance of this study comes from (1) its empirical outcomes regarding Grade 5 German students' epistemology about science and scientists were not examined till now (2) the possibility to realize the DAST, which is not applied in Germany yet and the new trend in this tool is that I asked students who drew the pictures to rectify my interpretations about their drawings and validating the test by asking their classmates to interpret also the pictures (3) I used the life of a charismatic German scientist of the 19th century to motivate students in designing and realizing independently from their teacher scientific activity (4) students drew their impressions about portfolios and their metaphors were also analyzed, a method not used in science and (5) students set the assessment portfolio criteria and they were an active part in the summative evaluation of the portfolio work with the teacher.

29. 1 Students' epistemologies about science and scientists.

The cross-national survey of Sjøberg (2001) realized in more than 20 countries, drawings and writings from 10 000 children about the image of scientists were collected. Among the outcomes of this project, is that children in many rich countries make drawings and write freely of scientists, they often depict them as cruel and selfish. They are always men, often rather ugly. They are experimenting with bombs, killing innocent animals etc. words like 'helping others' are never used when children describe what the scientists do. On the other hand, children in developing or in less affluent societies portray scientists very much like the heroic sort once one can saw them also in rich countries. These children portray scientists as intelligent and brilliant as well as kind and human. The scientists are the helpers and the heroes. They work for the benefit of everybody to make the world a better place to live.

The outcomes from the DAST, from the questionnaire administered to the class in order to comment on the 10 drawings of the focus group, as well as the focus group discussion showed that Grade 5 students presented many indicators of the stereotypical image of a scientist. The source of this image is the school and more precisely their teacher. But unlike students in the USA and Britain, Grade 5 students do not bear in mind the image of the crazy scientist. In addition, they still have the positive ideas about scientists as helpers and as good and brilliant people.

Before the project, all students drew scientists as chemists. They believed that scientists do their work only in the lab and trying to generate new knowledge. This image changed at the end of the project and remarkably, many of them believe now that scientists can be also women, and that scientists can work outside and having different research instruments.

29. 2 Is history of science an effective way in developing nature of science by students?

In spite of the political and legislative support in many school and higher education curricula across Europe, a report presented at a multinational conference in Strasbourg in June 1998 expressed widespread concern. The report put forward the view that while HST is well established as a strongly intellectual research discipline throughout the whole of Europe. Moreover, the report made a number of recommendations, mostly concerning graduate and undergraduate education including the strongly worded statement that HST should be made compulsory in the training of future schoolteachers.

Barth's view (1999) is from a German perspective, and epitomises the general view across the whole of Europe.

> *"…Pupils do not study the history of science, students and teachers do not know about the history of science, future teachers do not know about the history of science and new teachers do not teach the history of science to the next generation of pupils".*

29. 2. 1 Pro and against teaching of history of science.

The history of science has long been neglected in the secondary and tertiary curricula of Europe. However, the discipline has the potential to deliver a number of important educational objectives such as the effective teaching of science, helping to cement a common European culture (assuming for the moment that this is important) and humanizing the presentation of science suggests that the school science curriculum must move away from fragmented pieces of actual knowledge to consideration of issues where the science is less than secure and often controversial (Beyond 2000 Science Education for the Future, Millar & Osborne, 1998).

29. 2. 2 My position.

❖ Because we are still learning science with the 19th century teaching methods, students' beliefs about science and the scientific community are still of the 19th century! This thought was reinforced by the guide replying to my question concerning the Foucault pendulum at the Musée des arts et métiers, Paris. I asked him: "How Foucault had the idea to make this model in order to show the rotation of the earth?" He said that it was a "pur hasard", where during his visit to a manufacture that produces rotating machines; Foucault noticed that "une tige métallique était bloquée dans la machine à rotation, qui faisait toujours le même cercle". This observation made this scientist to look for a model to explain this phenomenon. It means that many discoveries started from a tiny observation and then one started to make questions and seeks to make a model to clarify or to visualize the observed phenomena. This "by chance" discovery or the so-called *serendipitious empiricism* mentioned in Solomon (1992) is what many students still believe what science is all about.

❖ During the time of searching for books about Humboldt, I read in a book dating of the 60s, in which the author advocates that it is very difficult to introduce the history of science in the classroom, although it is an important approach to make science more human and more accessible to students, because it still creates lots of tension about many historical non consensual events (even on the European level itself) (La Science contemporaine, p. 615).

30. Recommendations in teaching: my Teaching & Learning arrangement seen as a piece of 'Lehrkunstdidaktik'.

Although the allowed time of realizing the teaching setting was short, students became purposeful and independent learners and most of all they controlled their learning. These 3 acquiring factors: knowledge, awareness and control are the most important basic aspects of metacognition (Baird, 1986; Thomas & McRobbie, 2001). Unfortunately, the most important step I could not realize, because of the lack of time, was the class discussion when every group would present his work before the class.

For future teaching and learning researches, it would be advisable to repeat my intervention study on another age group and on larger scale.

If I had had more time, also, I could have realized an iteration process of teaching the subject, thus improving systematically the design of the teaching & learning arrangement. Although initially not planned so, my teaching and learning arrangement would then qualify for a "Lehrkunstdidaktik-Stück" (Berg, Klafki & Schulze, 1977-2003). The contours of such an "art-of-teaching piece", however, show up already now. This chapter gives an idea of this.

30. 1 Description of 'art-of-teaching didactics' or 'Lehrkunstdidaktik'*.

The term 'Lehrkunstdidaktik' or 'art-of-teaching didactics' is a didactical concept, which was developed since the end of the 1980s by the Educational Scientists Hans Christoph Berg (Marburg) and Theodor Schulze (Bielefeld) (Berg & Schulze, 1995) and it was integrated recently into the general education concept by Wolfgang Klafki (Klafki, 2003), in which it was set off as one of four dimensions of meaning ("Sinndimensionen") in general education ("Allgemeinbildung") under the heading "understanding the epoch-spreading mankind themes" („Verstehen epochenübergreifender Menschheitsthemen"). Knowing that the three other dimensions of meaning are: the "pragmatic dimension" („pragmatische Dimension"), described as related to "the so-called practical every-day-life", "the typical epochal key-problems of the modern world" or *„epochaltypischen Schlüsselprobleme der modernen Welt"*, such as peace or globalisation and "aesthetic awareness and design ability" („Wahrnehmungs- und Gestaltungsfähigkeit") (Klafki, 2003).

The term 'Lehrkunstdidaktik' encompasses 2 definitions:

- A first definition: Berg and Schulze place their art-of-teaching didactics in the tradition line of the Pedagogues Comenius, Diesterweg, Willmann, Haussmann and Wagenschein. The contact surface with Comenius "Magna didactica" lies (1st) in the contents of the term "Lehrkunst", holding that didactics (instruction guidelines) are rather an art than a scientific discipline, and (2nd) in the holistic approach ("omnia omnibus omnino" - teach everything to all in comprising way!); in fact, Comenius is touching directly the concept of Alexander von Humboldt's holistic vision on nature ("unity of nature"). The points of agreement with Diesterweg lie in the approach of the methodical processing of instruction combined with the decidedly democratic tradition. Willmann stands for the committment on "genetic teaching", on an instruction, which takes the learning processes of the child serious. Haussman believed that for each good instruction, i.e. for a lasting and an effective instruction, a drama element is indispensable. Wagenschein finally unified all the just mentioned criteria in his "genetic-socratic-exemplary instruction", the substantial innovation thereby, just enumerated, and is above all the postulate of the indispensableness of the

* My thanks go to Herr P. Buck for his invaluable help and advice in writing this part of my thesis.

discussion, i.e. that serious argument with the ideas and conceptions of the classmates function as catalysts and aid for self-understanding. (Berg 1993, Berg & Schulze 1995).

- ❖ A second definition emerged from quotations taken from (Berg & Schulze 1995): "teaching-art didactics are topic didactics", i.e. the "art-of-teaching" concept proceeds from content structures of ("mankind topics") and not from methodically formal stages. "Art-of-Teaching didactics are interested in the teaching methods that are brought along by the topic itself." "Preferably according to the usual cultural [instruction-] methods arrangements rather than the usual school methods!" and "take fewer topics out of the evolution of nature and more out of the evolution of mankind!" "Education concerns particularly personality development in the cultural tradition ("genetisch-dramaturgische Bildungsdidaktik")", "learning as meeting of subject and object". The Art-of-Teaching concept features are established in an iterative "optimization process of instruction units " (cf Berg, Klafki & Schulze, 1977-2003). They are designed as "didactical fables", i.e. they stand in a similar way for general instruction to other topics such as do fables concerning the behaviour of fable animals and fable situations for general human behaviour. (Buck, unpublished lecture handouts, winter semester 2002/03).
- ❖ Christoph Leder, a student, at the Pädagogische Hochschule Heidelberg, also summarized, complemented and formulated these two definitions, in a seminar in the summer semester 2003, as follows:
  - „Lehrkunstdidaktik ist eine **Inhaltsdidaktik**, sprich: die Methoden, mit denen gelehrt wird, richten sich nach dem Thema, das gelehrt wird. Unterrichtsdesign und Unterrichtsmethoden folgen der Struktur des Lehrinhalts.
  - Lehrkunst folgt einem **dramaturgischen Plan**, bzw. hat einen Spannungsbogen und erzeugt zielbezogen eine Spannung, die das Lernen vorantreibt.
  - Das Lehrkunstthema muss **Menschheitsthema** sein.
  - Das Thema muss einen **Motivationsanker** haben.
  - Lehrkunst kommt ohne **Dialog** nicht aus.
  - Es gibt nicht Lehrer und Schüler, sondern vielmehr **Längerlernende und Kürzerlenende**. Lehrer sind häufig, aber nicht immer die Längerlernenden. Sie lernen lebenslang, – auch wenn sie unterrichten." (Handout by Christoph Leder fort he session of july 14, 2003)

30. 2 Why is my Teaching & Learning arrangement can be regarded as a 'Lehrkunst-Stück'.

The 6 points cited above forming the standards of the 'Lehrkunstdidakitk' approach fitted by excellence to my teaching setting:

1. Students as well as teachers learn from each other's. These were my thoughts when I read students' portfolios, which encompassed diverse content knowledge relative to scientific themes, about nature (e.g., wild animals) and about natural phenomena (e.g., volcanoes). Moreover, students learn from each other's during presenting their themes to the class and while assessing their portfolios.
2. My teaching practice was dependent of the learning situation. Since students set their questions, my role as a teacher is to collect for every theme the relevant books and materials, as well as accompanying every group in the peer- instruction and discussing the potential faced difficulties. There was not a moment, where there was for instance a frontal class. In other words, I had to expect any possible improvised difficulty.

3. The 'motivation anchor' was set at the very beginning, when students were asked to formulate questions of their interest and to work as scientists. This provides an easy and fruitful atmosphere during the whole project.
4. Besides acquiring factual knowledge, students learned the way to look for a specific scientific issue, to decide by them what information is relevant. In other terms, to be independent of their teachers when learning.
5. Students were not any longer knowledge-receivers. On the contrary, they were trying to discuss with their teacher how they can go further in finding ways to answer their questions. In other words, students had achieved a 'genuine understanding' (Buck, 2001).

In sum, I was convinced by Martin Wagenschein's teaching practice, which has 3 aspects: Exemplarisch-Sokratisch-Genetisch:

> *My deepest motive force is the cleavage between an original feeling-at-home with nature and a strong fascination by physics and mathematics, and the ensuing irritation by the growing alienation between man and nature effected by science, starting early at school. My pedagogical aim is to overcome – still better to avoid – the cleavage by an educationally centered humanistic physics teaching* (Wagenschein, 1962, p. 9, translated by W. Jung and cited in Matthews, 1994, p. 212). – Die Pädagogische Dimension der Physik.

30. 2. 1 The Teaching Setting Similarities

Wagenschein background: he was a dedicated science teacher	**Me too!**
Exemplarisch A student every-day-life natural phenomenon as an example that *interest* students. The phenomenon is chosen by the teacher and it must be representative (quality of the phenomenon, that's why he had discussed around 40 phenomena). A question about the phenomenon is raised first by the teacher. The phenomenon is approached through the Socratic discussion in a holistic way. Once the phenomenon is discussed, students could study it with hands-on activity.	**Exemplarisch** A brainstorming session: talking about the life and work of a scientist of history (here a good example of quality and representing science inquiry) to give impulse to students in order to arouse their interests. Students choose a phenomenon of their interest to investigate.
Sokratisch (Verstehen exaktes Denken) An effective teacher-student discussion/ brainstorming of a phenomenon. **The classroom setting:** students sit in a circle, the teacher guides the discussion and the atmosphere must be engaging. **The teacher's role (or länger Lernender):** helping students to reach by themselves an explanation to the phenomenon by discussing with them their thoughts, where every thought is taken into consideration. The teacher should take care that all participate in the discussion, boys and girls. **The students's role (or kürzer Lernender):** the problem must be discussed together as in a friends' circle, with a free head or "kein Kramen im Gedächtnis" using their own language and they must be understandable by all the class, without shyness because no one is assessed.	**Sokratisch** A classroom discussion about every question to fix the student thoughts about his *phenomenon.* **The classroom setting:** students can work alone or in groups of 2 and more. The atmosphere is engaging. **The teacher's role:** is a peer-instructor and he takes care that every student has the relevant materials, books and the internet links. **The student's role:** an independent learner from his teacher, but he gets counselling from his teacher, friends, parents and experts. At the end of the investigation, students communicate their findings to their classmates in form of a poster, portfolio and a presentation and subsequently there is a class discussion.
Genetisch (development of students' metacognition first and then hands -on skills development) Developing knowledge by the student about a natural phenomenon through a classroom discussion that convinces the teacher understanding. In this way, student is able to acquire implicitly or explicitly the historical development of a scientific concept and not the ready knowledge in the science book (right or wrong, in the traditional set) and subsequently he will reach by himself the state of "Verstehen" that is related to his preconceptions, his daily experience and *his feelings* about the phenomenon.	**Genetisch** Students develop and arrange by themselves their learning milieu. Their learning strategy is thus an individual performance.

30. 2. 2 The teaching setting discrepancies

Wagenschein teaching practice	My teaching practice
Is realized as a block-schedule teaching	Is realized as a school project
The teacher chooses the natural phenomena and he may pose at the beginning the first question	The student chooses the natural phenomena of his interest and formulates the question after the PPT about Humboldt's life
The teachers guides the class discussion till the phenomenon is clarified	The student has to search by himself answers to his questions. In this way, he will develop and be aware of his learning strategy
The teaching process has just one form: formulating a question (or more), discussing it in a circle and finally making a conclusion(s)	The teaching-learning arrangement depends of the learning situation
The task of the teacher is to unpack students' answers	Students communicate their findings in an aesthetic way and conform to the current scientific forms (poster, presentation)
Student's understanding develops through discussion	Student's understanding develops through discussion, using books and aid materials (internet) and peers (experts and family) [instrumentalist competencies]

Wagenschein taught physics and mathematics for high school students	**5th and 6th Gradesstudents in NWA and NPH subjects**
The phenomenon may be approached in a holistic way	**The phenomenon is approached depending on student interest**
Students' reflections are not noted and time is short for this mental activity	**Students' reflections are noted in portfolios and it occurred during the whole learning process**
The assessment was foreign to Wagenschein and he did it in a simple way	**Students are an active partner in assessing their classmates' work. The assessment was done in a sophisticated way**

30. 3 A sketch of Alexander-von-Humboldt-Lehrkunst-Stück.

My learning arrangement approach is represented as follow:

***Title of the teaching play*: ": "Alexander von Humboldt – oder: Was passiert eigentlich, wenn einer ein Forscher ist?"** ***Teacher and Autor:* Suzanne El Takach** (supported by Torsten Eggert and Peter Buck) ***To Topic of basic human activity ("Menschheitsthema"):* science is a social enterprise; it affects crucially the culture development; we are, in the science society, crucially depending on it.**
First test realization: in NWA in Grade 5d at Linkenheim Realschule, by the end of the school year 2002/03. The instruction play has 4 acts as well as a prologue and an epilogue.
Scene sequence **Prologue:** The teacher holds a lecture on the life of the very remarkable Alexander von Humboldt. It is one the most grandiose and the multi-facetted Naturalist. The prologue is aimed to throw the "motivation anchor". It counts on the internal, factual as the positively emotional commitment of the teacher.
1st. Act: What picture do we have ourselves about scientists? – Students draw pictures, which are observed and commented together.
2nd. Act: The principal activities of the scientist are among other things: observing, finding relevant information, inferring and formulating questions- we go into a typical analysis situation. "Socratic" discussion about Tricky Tracks activity: observation versus inference (Lederman, 1998).
3rd. Act: We are scientists: We develop "our" questions and try to answer them. – open learning instruction, Portfolio work, presentations, own and other classmates Portfolio assessment.
4th. Act: After these experiences, which we made by ourselves, we watch and interview a scientist, who, like Alexander von Humboldt, did research. We select (conforming to the topics of research selected by the students) one of Humboldt main research areas: Volcanism. We invite a specialist to a lecture, because research needs authenticity. He holds a lecture (with slides) on his findings at the volcano Etna on Sicily. At the end in a class discussion we notice: tricky tracks was absolutely a good picture (a metaphor) for the research process; now are able now to observe better, to acknowledge each other's questions, documenting our findings in portfolios, and during the provision of information, we can make interpretations and we can know that answers are provisional.
Epilogue: We look together back on the process, by which we passed through together and see that research changes us. We see also that: Research requires ideals: objectivity, rationality, engagement, organization, evaluation.

30. 4 Concluding remarks.

The German writer Enzensberger believed that: „Es ist eine nationale Aufgabe, junge Menschen wirken lassen, das Enthusiasmus, mit dem Humboldt seine riesigen Unternehmen realisiert hat" (cited in Volker Breidecker article in Die Süddeutsche Zeitung, 19 August, 2004).

Deci and Ryan who developed The Self-Determination Theory (SDT), advocate that the intrinsic motivation results in high-quality learning and creativity and that educators have to enhance the intrinsic motivation through the extrinsic one (Ryan & Deci,2000). Note that this theory has 3 guidelines: intrinsic motivation, extrinsic motivation and autonomy in learning.

My approach was to use Humboldt's life and scientific discoveries as a mental impulse to students in order to make them think about a problem of their choice to investigate. Students enjoyed of an autonomy- supportive learning climate (Williams & Deci, 1998) supported by a frequent (Levesque, Zuehlke,, Stanek and Ryan, 2004), personalized (Butler & Nisan, 1986) and meaningful (Williams & Deci, 1998) feedback, which are 3 necessary aspects of instruction that contribute to enhance students' intrinsic motivation.

Finally, Alexander von Humboldt made all his discoveries with a great *enthusiasm*. This was the keyword in my work with students: *enthusiasm* leads to *motivation* and this produced a *commitment* to work.