How Shall We Teach Chemistry. First Approaches to Didactics of Chemistry in the Nineteenth Century

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Confronted with relatively bad results of the medical students in chemistry the question arose, "why". Is there a problem with the chemistry classes at school? Or, where else could the disinterest in chemistry originate? It is now well recognised that chemistry is an unpopular subject at school. Whereas the pupils start the classes with many expectations, questions and interest they change their opinion after a short time. There are different reasons for this development; chemistry school teachers, university teachers and *didacts*[1] are investigating this problem very seriously. They have made proposals for improvements in teachers' education and developed new models for chemistry classes, such as, "Chemistry for life"[2] or "Chemistry in context".[3]

It is interesting also to attempt answer the following question: How was the situation in that time in German speaking countries when school level chemical education started? The history of chemical education at universities is already investigated very well. In the literature there is much information about chemistry as *ancillary science* for medicine or metallurgy before the nineteenth century, the institutionalisation of chemical studies as a fully recognised science and further discussions about problems between universities and "Technische Hochschule" (Technical University)[4] during the nineteenth century.

Some aspects of the development of chemical classes at school are investigated in some older papers, too. But in the earliest reports on teaching realities the special term "chemistry" is not used, the courses were characterised as natural history, for instance, natural objects for "recreation" are described in the school program of August Hermann Francke (1663-1727),[5] one of the most important exponents of pietism. Further on, the acquaintance with realities is an attribute of the philanthropical pedagogy which had a long lasting influence on teaching practise in *Volksschule* (elementary school). In the German high school (*Gymnasium*) chemistry courses often failed until the end of the nineteenth century. Details about the situation in the Rhineland in the nineteenth century have been described by

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Halasik,[6] detailed discussions about school laws in the publications of Bonnekoh[7] and Schoeler,[8] a first overview about schoolbooks was made by Just[9] and can be found in "Communicating chemistry".[10] A good overview on chemical textbooks used in academic teaching is the doctoral thesis of Haupt.[11] A more detailed analysis of German chemical textbooks on the background of the invention of *Theoretische Chemie* in the period 1775-1820 is given by Frercks and Markert.[12] Questions of popularisation played an important role for the development as scientific discipline as well as for chemical education.[13]

These different points of view were connected to clarify the question: What does chemical education mean in the nineteenth century? The influences on (chemical) education should be considered, for example the current state of scientific knowledge, the role of systematisation and knowledge classification as well as technical and economical conditions. In addition, there are several factors which accelerate or retard the development of chemical education, such as educational policy, the acceptance of the science in the society, philosophical views, progress in institutionalisation and the developments in pedagogy and didactics. The connection between chemical education (at school and/or at university) and the genesis of chemistry as a discipline should be much better shown. Furthermore, it should be interesting to see if there are persons, other than Justus Liebig (1803-1873),[14] who influenced chemical education (either popular, school or university education). In which way were they (academics and/or non-academics) encouraged? When and why can we find any qualitative changes in textbooks and in teaching chemistry concerning the didactics and methods? Where are the roots of the methodology/didactics of chemistry? Which tools were used in chemistry classes at school?

Concerning the question of establishing chemistry as a discipline the description of Laitko will be followed, "disciplines are self-reproducing systems of scientific activities".[15] Knowledge of the discipline is necessary for the internal reproduction which is usually (in the case of scientific disciplines) taught at university. If this knowledge already has got a basis at (secondary) school the results will be much better. At the first glance it could seem that a discipline is not more than a (school or university) subject, but in reality must include the knowledge and the skills that are necessary to produce new knowledge. Around 1800 the first stage of discipline genesis for chemistry was reached, as Guntau explained there was a lot of connecting elements in the scientific thinking; the individual scientific disciplines were recognised not only by the scientific community, but by the public.[16] The classical disciplines (mechanics, chemistry, botany, zoology and geology) were established; natural history including the concept of the three natural "habi-

tats"[17] became obsolete, however this was a very slow process. At the universities the knowledge no longer had a more or less fixed form; the students were confronted with developing knowledge. The faculties of Philosophy got the task to educate teachers for the humanistic High school (*Gymnasium*) or the *Realgymnasium*".[18] The aim of education in these schools was similar to that in the philosophical faculty, only modified by the age of the pupils. The teachers studied science, and the knowledge corresponded to the current results in science. Relevant professional skills (pedagogy, methodics, didactics, and psychology) were not taught.[19]

All the mentioned problems and questions can not be answered in this paper; the main focus herein is the role of chemists which could be described as early didacts of chemistry.

Some important German didacts of chemistry in the nineteenth century

In this paper it is only possible to show a small part of all the outlined problems. Especially attention will be paid to the didactic work of Julius Adolph Stoeckhardt (1809-1886). After that the practise of Julius Eugen Wagner (1857-1924) will be illustrated. Stoeckhardt started to teach natural science, later chemistry in the 1840's. The endeavours for didactics in chemistry by Wagner are about 60 years younger, Stoeckhardts point of view has a touch of natural history, Wagners is characterised by an already specialised chemistry, which means physical chemistry. This can be best understood if it is recognised that Wagner was a pupil of Wilhelm Ostwald (1853-1932).

Julius Adolph Stoeckhardt - his biography

Julius A. Stoeckhardt was a multifunctional character: a scientist, a chemist and a teacher.[20] In the space available it is not possible to discuss his role as a propagator in agricultural chemistry, about his controversy with Liebig about the role of nitrogen, about his work on toxicity of several colours used in the nineteenth century or about his results on the damage of forest by fumes. After an apprenticeship and employments in several pharmacies Stoeckhardt studied natural sciences in Berlin from 1832 to 1833. Heinrich Rose (1795-1864), Eilhard Mitscherlich (1794-1863), Sigismund Friedrich Hermbstaedt (1760-1833), Heinrich

Friedrich Link (1767-1851), Karl Sigismund Kunth (1788-1850) and Henrich Steffens (1773-1845) were his scientific teachers. After a journey through Europe with visits to famous chemists such as Michael Faraday (1791-1867), Joseph Louis Gay-Lussac (1778-1850), Antoine Laurent de Jussieu (1748-1836) and Jean Baptiste Dumas (1800-1884) he started to work in the laboratory of the mineral-water-production of Friedrich Adolf Struve (1781-1840) in Dresden. At that time he was acquainted with Georg Paul Alexander Petzholdt (1810-1889), who lectured *privatim* and who had a laboratory for his students private use. It is reported that Stoeckhardt worked in this laboratory, Franz Varrentrapp (1815-1877) also possibly worked there.[21] In 1837 Stoeckhardt became a teacher of natural sciences in the "Vitzthumsche Geschlechtergymnasium" [High school of the Vitzthum dynasty, donated by Rudolph Vitzthum von Apolda (1572-1639)] in Dresden, which was combined with "Blochmannsche Erziehungsanstalt" [Boarding school of Karl Justus Blochmann (1786-1855)] since 1828. It is unknown in which way Stoeckhardt taught natural sciences. But every school program from 1830 to 1837 informs about physical and chemical practical work of the pupils. In 1835 a special house could be used for laboratory work. This was very progressive for the time. It must be noted that there were three types of school: the "Progymnasium", the "Gelehrtengymnasium" and the "Realgymnasium".[22] In the school program from 1834 Snell reported about the agreement of teaching realities in "Gelehrtengymnasium", not only with the aim to teach knowledge which can be useful for life (which is highly required by philanthropism) but on the background that realities are playing an important role as instruments in general education. Chemistry under the practical aspect was taught in the "Realgymnasium". Snell demanded the systematic teaching in natural science, especially.[23]

Stoeckhardt's Doctorate

The Doctoral thesis of Stoeckhardt at the University of Leipzig was titled: *Res Naturales, qua de causa perscrutandae, qua methodo docendae et tractandae, quomodo maturae convenienter disponendae*[24] (the natural objects, why should they be investigated, which method is used for teaching, in which way the nature is adequate described). The first question about the necessity of a treatment of nature was answered with words from Carl von Linné (1707-1778): "Alles was dem Menschen zum Nutzen gereicht, wird von diesen natuerlichen Coerpern hergenommen. … Daher giebt sich von selbst zu erkennen, wie nothwendig die Erkenntniß der Natur sey.[25] (Anything what is useful for human beings comes from natural matters. So it goes without explaining why the cognition of nature

is necessary). However, for Stoeckhardt the highest aim of cognition of the nature was the cognition of god in nature and the worship of god in nature. Stoeckhardt had a teleological point of view because he accepted that in all objects there is usefulness. It can be assumed that Stoeckhardt was influenced by natural philosophy (in Berlin he visited lectures of Steffens who taught natural philosophy with speculative direction) and he was influenced by the empirism of Francis Bacon (1561-1626). In the second part of his thesis Stoeckhardt made proposals about the methods which should be used in teaching natural sciences. Here one can find many similarities to opinions of August Hermann Francke[26] or of Ehrenfried Walter von Tschirnhaus (1651-1708).[27] Stoeckhardt demanded to use only a few examples, as lot of examples would strain the memory of the pupil. It is better to discuss some examples very intensively. The examples chosen should have a connection to the surroundings of the pupils (this is still very important for beginners courses today). Stoeckhardt recommended to show the natural objects and to do experimental work because this is very good for the memory. Every time the teacher should start with simple examples, further on he can use more complex ones. In the third part, Stoeckhardt explained his scheme for natural sciences after discussing the role of several schemes and the criterions for these schemes. He divided nature into matter and forces, but he stressed that forces can not exist without matter (and vice versa). Matter exists in three forms, namely, Organica, Atmosphaera and Inorganica. In the opinion of Stoeckhardt the atmosphere which includes air and water must have a special place in the scheme because life can not exist without air and water and the inorganic part is formed by water and air, too. He divided Organica and Inorganica into further disciplines that he then connected again in the three fundamental disciplines: Geologia, Biologia and Atmosphaeriliologia. Stoeckhardt believed that these are the constituent parts of natural history. The application of the term "biology" is somewhat astonishing for the period. Even though biology was "innovated" by Jean-Baptiste de Lamarck (1744-1829) and Gottfried Reinhold Treviranus (1776-1837) and in some earlier sources of the term are found it is hard to describe the exact meaning of "biology" in that time as Kanz established.[28]

In the same way he divided the forces into inorganic and organic forces and in *vis vitalis* (by the way, in his life Stoeckhardt never got over the question of vitalism[30]). Then he gave various examples for transformations of the forces (the word force is often used for energy in the modern sense). It can be established that Stoeckhard knew of the current developments in science. Stoeckhardt expressed his opinion that schemes are helpful tools but the pupils must learn to connect the different parts again to obtain the whole view of nature. In this way Stoeckhardt

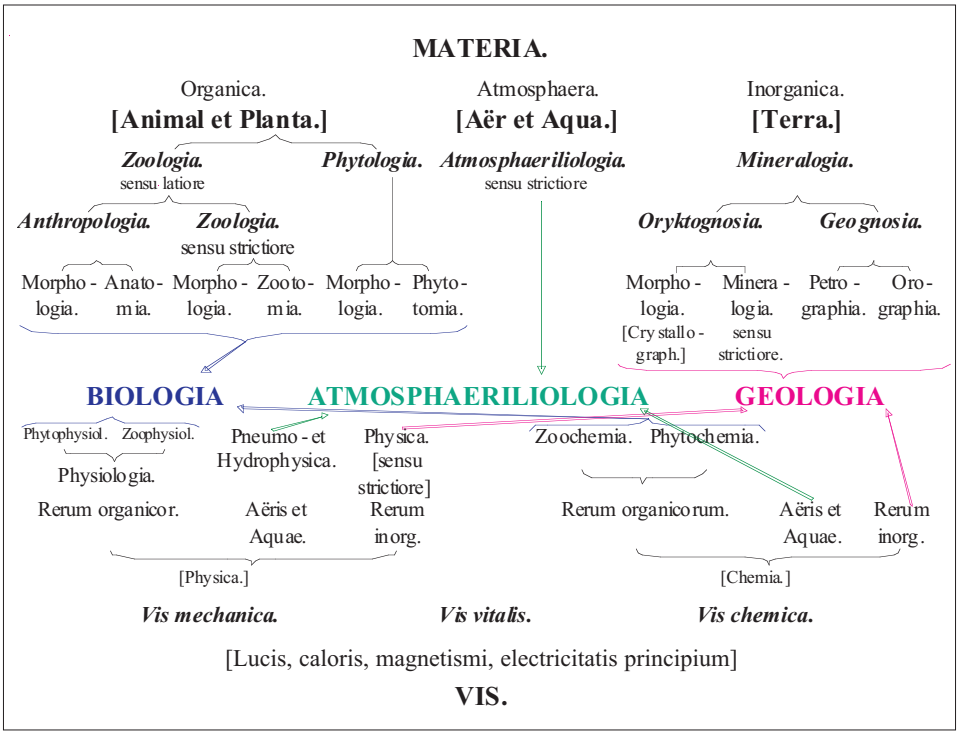

Figure 1: The scheme of Nature used by Stoeckhardt in his doctorate[29] (slightly modified in the format).

propagated one natural science (it is interesting that in some modern schools you can find attempts to teach natural sciences instead of chemistry, physics and biology). One can reason that Stoeckhardt followed the fundamental views in the didactics of natural sciences which were already established in the seventeenth and eighteenth centuries. He followed the general view of natural science, like in natural history, but he did not use the old three "empires" (or habitats) (mineralogical, animal and vegetable), he still regarded that matter and the forces were divided in three parts.

From 1838 to 1847 Stoeckhardt was a teacher of natural sciences at "Koenigliche Gewerbschule" (Royal Vocational School) in Chemnitz, he taught experimental physics (4 h.), experimental chemistry (4 h.), technical chemistry (3 h.), practical courses in chemistry (8 h.) and some hours on botany, mineralogy and natural history. Stoeckhardt's view of the nature was represented in his schedule.

Schule der Chemie – one of the most popular books of the nineteenth-century century

With regard to Stoeckhardt's role in didactics we must discuss his book, "Schule der Chemie" (first edition in 1846). This was a very successful book, 19 editions were made by Stoeckhardt, the book was translated to several foreign languages (the translation to Japanese was the first chemical textbook in Japan[31]). In the foreword to the second edition Stoeckhardt again had a critical look at the methods of teaching. He did not agree completely with Bacon, who said that it is dangerous for teaching a science to choose a strong systematic way in teaching it. Stoeckhardt defended the opinion that for beginners, every teacher should prefer a systematic course. Stoeckhardt "translated" the strong scientific language into popular descriptions. He chose examples and experiments from the surroundings of the readers. But his book was not a typical popular exposition, primarily it was a textbook, he wrote this book for use in his own chemistry lessons at "Gewerbschule". But a second reason was indeed a popular. Stoeckhardt recommended stores in the book, where the readers could buy chemical compounds and apparatus. He gave a lot of examples of experiments which were easy and connected with experiences of the readers. Some of the experiments are useful even in our days; you can find some of them in current didactic papers (for instance the experiment of boiling water with the help of ice[32]). In describing the chemical problems Stoeckhardt often followed the nomenclature of a "describing" science. Even in the last edition he edited of "Schule der Chemie" organic chemistry is chemistry of vegetable and animal matter. Only Ernst Lassar-Cohn (1858-1922) (who edited the "Schule der Chemie" after the death of Stoeckhardt) used in his editions the already well established definition of organic chemistry as chemistry of the carbon compounds. So we can deduce that Stoeckhardt followed only to some degree new theories in chemistry. In 1868 he discussed the new atomistic theories but in organic chemistry he used the old theory. He tried to find a system for his elements using a parabolic arrangement,[33] but he never mentioned the system of Dmitrij I. Mendeleev (1834-1907).

It is difficult to explain why his book was so successful. You can find other books with similar experiments, written in a popular manner. For instance Emil Postel (1813-1875) wrote the book "Laienchemie"[34] (Chemistry for amateurs) in 1857. He emphasised that his book was much cheaper than the "Schule der Chemie"! Postel's experiments do not differ much from those of Stoeckhardt. Postel preferred a style which connects the author with the reader (he often use "we are doing" etc). We do not know the exact difference in the price, only that Stoeckhardts book had many more editions than Postel's. However, we know that Adolf

von Baeyer (1835-1917), Emil Fischer (1852-1919) and Wilhelm Ostwald (1853-1932) all used the "Schule der Chemie".

Wilhelm Ostwald, Julius Wagner and the first Professorship of Didactics in Chemistry

In 1903/04 Wilhelm Ostwald wrote a "Schule der Chemie",[35] too. There are of course a lot of differences in the contents because the 60 year interval brought a considerable development in chemical knowledge. A big difference can be observed in style. Ostwald used a very old method, the dialog between a teacher and a pupil. Ostwald was very engaged in problems of teaching chemistry at school.[36] There are some legends which refer to the very good teaching style of Ostwald.[37] Ostwald taught mathematics and natural sciences in a school in Dorpat for one year. When he came to Leipzig in 1887 he established a practical course for teachers. He mentioned that it is not useful for teachers to have *only* an all-embracing experience in chemical analysis the future teachers must have primarily experiences in doing school experiments. This special course was supervised by Julius Wagner[38] who had passed a special examination for teachers but he never taught chemistry at school. Nevertheless Wagner was very successful in his courses. There is no information about the contents of these courses. We only know that Wagner lectured didactics in chemistry. There is no information about his research work in didactics; there are some Doctoral theses which Wagner had supervised. But it is difficult to distinguish if the first initiative came from Wagner or from Ostwald. However, Ostwald strongly supported Wagner activities. It was Ostwald, who applied for an extraordinary Professorship in didactics for Wagner. This was established in 1901 and from 1904 with a budget. There are only two didactic papers written by Wagner. The first was his inaugural lecture on the occasion of his Professorship[39]. He dealt with the chemistry lessons for beginners in school because he thought that it is useful if university teachers gave recommendations for schools since universities are confronted with the results of school teaching. He compared the different methods in teaching: the academic or systematic one, the methodical and the historical one. He underlined the importance to start with well-known things, which are easy to understand and then to go stepwise to more complicated problems (this method was used by Rudolf Arendt (1828-1902)). Wagner developed his own course, summarised as follows:

1. Distinction of substances on the basis of properties
2. Separation of substances on the basis of differences in their properties
3. Physical changes of substances (changes of the aggregation state)

4. Separation on the basis of changing the aggregation state
5. Chemical changes of substances, Separation, Synthesis
6. Quantitative laws about the constitution of a compound
7. Reverse reactions and the chemical equilibrium
8. Rate of the reaction and the acceleration of the reaction with the help of extrinsic objects, which has the name catalysis.[40]

It is interesting that there are similarities in the contents and in the sequence of teaching to actual strategies of teaching chemistry for beginners. When the pupil finished this course he was prepared for systematic instructions of chemistry, which should be done only at higher schools. Concerning the practical work Wagner proposed the following way:

"to measure and to weigh, to do experiments on the properties of the substances, to change the volume by changes of pressure and temperature, to do experiments on the density, to change the aggregate state, to separate substances: filtrate, distillate, sublimate, dissolve; estimation of water in the vitriol of copper, estimation of water and carbon dioxide in $NaHCO_3$, estimation of the amount of oxygen which is produced from mercuric oxide, instruction in the synthesis of simple organic compounds, experiments with reversible reactions, on equilibrium and on the reaction rate, simple gravimetric and volumetric determinations".

In his second paper[41] Wagner demanded that university teachers had to develop teaching methods for school, they had to stress that chemical courses at school are necessary for general education. He criticised that teachers were badly educated, that teaching methods were not thought over and that good school-textbooks were not available. Wagner himself tried to improve the education of teachers. But his results in developing new methods or new textbooks were very poor. After Ostwald left Leipzig University Wagner did not write any more didactic papers but he continued to carry out the special practical courses for teacher students. With the Professorship he had the chance to do a lot for "Chemistry in school", but he did not achieve as much as might have expected.

Conclusions

This paper is an attempt to describe factors which influenced the chemical education in the nineteenth century in Germany. The centre point is discussion the opinions of Stoeckhardt on teaching chemistry and "nature" respectively. He picked up ideas from the pedagogy of pietism and philanthropism and he used

several schemes which seemed useful to him to describe nature for school education. Although never special trained in pedagogy or didactics he was successful in classes, in papers and in lectures.

Some 60 years later Ostwald made demands on such special training for teachers and he introduced courses for prospective teachers. He tried to institutionalise the didactics of chemistry with the establishment of the first German Professorship for this subject.

Notes and references

[1] A didact (*Didaktiker*) is a university, college or school teacher who has a scientific interest in the know-how of teaching itself and the contents of teaching.

[2] Compare for example: Julia Freienberg, Waltraut Krueger, Gabriele Lange, Alfred Flint, "Chemie fuers Leben auch schon in der Sekundarstufe I – Geht das?", *Chemkon* 2 (2201): 67 and 1 (2002): 19.

[3] See for example: <http://*www.chik.de*>

[4] Dorothea Goetz, "Naturwissenschaftliche Aspekte der Deutschen Aufklaerung", *Jahrbuch fuer Wissenschaftsgeschichte* (1974) II: 99-120;
Christoph Meinel, "Das Forschungslaboratorium und die Organisation des chemischen Hochschulunterrichts", in *Naturwissenschaftsdidaktik: Sommersymposium Essen 1993*, Naturwissenschaft und Unterricht – Didaktik im Gespräch, Bd 21, ed. Altfrid Gramm, Helmut Lindemann und Elke Sumfleth (Essen: Westarp, 1994), 187–206;
Regine Zott, *Gelehrte im Fuer und Wider (*Muenster: LIT, 2002).

[5] Dorothea Goetz, "Der Anteil des Pietismus an der Herausbildung des naturwissenschaftlichen Unterrichts im 18. Jahrhundert", *NTM-Schriftenreihe Naturwissenschaften, Technik, Medizin* 11 (1974): 95-102.

[6] Anna Margret Halasik, *Der Chemieunterricht waehrend des 19. Jahrhunderts im Rheinland, Beitrag zur Geschichte des Chemieunterrichts im 19. Jahrhundert; dargestellt an ausgewählten Beispielen aus dem Rheinland* (Witterschlick/Bonn: Verlag M. Wehle, 1988).

[7] Werner Bonnekoh, *Naturwissenschaften als Unterrichtsfach* (Frankfurt/Main: Lang, 1992).

[8] Walter Schoeler, *Geschichte des naturwissenschaftlichen Unterrichts im 17. bis 19. Jahrhundert* (Berlin: Walter de Gruyter, 1976).

[9] Norbert Just, *Geschichte und Wissenschaftsstruktur der Chemiedidaktik* (Muehlheim: Westarp, 1989).

[10] Bernadette Bensaude-Vincent, Anders Lundgren (ed.), *Communicating Chemistry: textbooks and their audiences, 1789-1939* (Canton, MA: Science History Publications/USA, 2000).

[11] Bettina Haupt, *Deutschsprachige Chemielehrbuecher (1775-1850)* (Stuttgart: Dt. Apotheker-Verlag, 1987).

[12] Jan Frercks, Michael Markert, "The Invention of Theoretische Chemie: Forms and Uses of German Chemistry Textbooks, 1775-1820", *Ambix* 54 (2007) 2: 146-171.

[13] Andreas W. Daum, *Wissenschaftspopularisierung im 19. Jahrhundert: buergerliche Kultur, naturwissenschaftliche Bildung und die deutsche Oeffentlichkeit, 1848-1914* (Muenchen: Oldenbourg, 1998).

[14] Regine Zott, Emil Heuser, *Die streitbaren Gelehrten: Justus Liebig und die preußischen Universitaeten* (Berlin: ERS-Verl., 1992) and other papers and books about Liebig such as Adolf von Baeyer, *Liebigs Verdienste um den Unterricht in den Naturwissenschaften* (München: C. Wolf und Sohn, 1892); Willi Conrad, *Justus von Liebig und sein Einfluss auf die Entwicklung des Chemiestudiums und des Chemieunterrichts an Hochschulen und Schulen* (Darmstadt: TH Darmstadt, 1985); Regine Zott, "Liebig und Ostwald, Praktiker und Theoretiker von Chemiebildung", in *Chemie in der Schule* 37 (1990) 10: 369-374; William H. Brock, *Justus von Liebig* (Braunschweig/Wiesbaden: Friedrich Vieweg & Sohn VerlagsGmbH, 1999).

[15] Hubert Laitko, "Die Disziplin als Strukturprinzip und Entwicklungsform der Wissenschaft – Motive, Verlaeufe und Wirkungen von Disziplingenese", in *Verhandlungen zur Geschichte und Theorie der Biologie*, Vol. 8 (Berlin: VWB, 2002), 19-55.

[16] Martin Guntau, "Wissenschaftliche Ideen und wissenschaftliche Kommunikation in der ersten Haelfte des 19. Jahrhunderts", *Rostocker Wissenschaftshistorische Manuskripte* 20 (1991): 9.

[17] Wolf Lepenies, *Das Ende der Naturgeschichte: Wandel kultureller Selbstverstaendlichkeiten in den Wissenschaften des 18. und 19. Jahrhunderts* (Frankfurt(Main): Suhrkamp, 1978).

[18] Education in Humanistic High Schools was focussed on Latin and Greek. In the "Realgymnasium" there education in natural sciences played a larger role. This type of school was established in the beginning of the nineteenth century and formal recognised in the middle of that century. The certificate of the Realgymnasium allowed the enrolment at university, at the beginning with some limitations.

[19] If we distinguish pedagogy, methodics, didactics we have to define the contents of these items: pedagogy (from the greek word „*paideia*") is the knowledge about education, instruction/teaching and learning. Didactis (the greek „*didaskein*" means teach) is a part of pedagogy, in the focus we find the question of teaching- and learning matter (methodics concerns the know-how of teaching). Sometimes there the word "Mathetics" is used, too. This word is based on Johann Amos Comenius (1592-1670) who divided in didactics (the "art" of teaching) and mathetics (the "art" of learning"). I do not use this strong disjunction.

[20] Biographical data can be found in: Ernst Theodor Stoeckhardt, *Stammtafel der Familie Stoeckhardt*, 1883, maschinengeschriebener Auszug von Regina und Hilmar Stoeckhardt, angefertigt 1982; Otto Wienhaus, "Julius Adolph Stoeckhardt - a pioneer of applied chemistry", *Fresenius J. Anal. Chem*. 363 (1999): 139-144; Otto Wienhaus, Walter Loescher et al., "Julius Adolph Stoeckhardt - ein Wegbereiter fuer die interdisziplinaere Arbeit, die Zusammenarbeit mit der Praxis und die Popularisierung wissenschaftlicher Erkenntnisse", *Z. Chem*. 26 (1986) 8: 269-275; Friedrich Nobbe, "Julius Adolf Stoeckhardt", *Tharander Forstliches Jahrbuch* 37 (1887): 76-85. Max Wilsdorf, "Julius Adolf Stoeckhardt und seine Thaetigkeit in Chemnitz", *10. Jahresbericht der Landwirtschaftlichen Schule* 10 (1887): 5-15.

[21] Herbert Poenicke, "Georg Paul Alexander Petzholdt; ein mitteldeutscher Naturforscher und Lehrer in Rußland (1810-1889)", *Hamburger mittel- und ostdeutsche Forschungen: kulturelle und wirtschaftliche Studien* 2 (1960): 47-70.

[22] "Progymnasium" is a preparatory school for the High School, "Gelehrtengymnasium" is another name for Humanistic High school, for that and for "Realgymnasium" compare 18.

[23] Karl Christian Snell, *Ueber Zweck und Einrichtung eines Realgymnasiums* (Dresden and Leipzig: Arnoldsche Buchhandlung, 1834).

[24] Julius Adolph Stoeckhardt, *Res Naturales qua de causa perscrutandae, qua methodo docendae et tractandae, qumodo naturae convenienter disponendae* (Dresden: B. G. Teubner, 1837), translation from Latin to German unpublished, my thanks for translation to Friederike Neumeyer and Daniel Faustmann.

[25] Johann Joachim Langen, *Caroli Linnaei...Systema naturae, sive regna tria naturae systematice proposita per classes, ordines, genera et species = Natur-Systema, oder die in ordentlichem Zusammenhange vorgetragenen drey Reiche der Natur, nach ihren Classen, Ordnungen, Geschlechtern und Arten* (Halle: Gebauersche Schriften, 1740).
[26] August Hermann Francke, *Ausfuehrlicher Bericht vom Waysen-Hause, Armenschule und uebriger Armenverpflegung zu Glauchau an Halle* (Glauchau: Verlag des Waysenhauses, 1701).
[27] Ehrenfried Walter von Tschirnhaus, *Gruendliche Anleitung zu nuetzlichen Wissenschaften, absonderlich zu der Mathesi und Physica, wie sie anitzo von den Gelehrtesten abgehandelt werden* Faksimile-Neudruck der 4., vermehrten und verbesserten Auflage Frankfurt und Leipzig 1729 (Stuttgart-Bad Cannstatt: Friedrich Frommann Verlag, 1967).
[28] Kai Torsten Kanz, "Biologie: die Wissenschaft vom Leben? – Vom Ursprung des Begriffs zum System biologischer Disziplinen (17. bis 20. Jahrhundert)", in *Lebenswissen, Eine Einfuehrung in die Geschichte der Biologie*, ed. Ekkehard Hoextermann and Hartmut H. Hilger (Rangsdorf: Natur&Text in Brandenburg GmbH, 2007): 100-121.
[29] Stoeckhardt, Res Naturales, addendum.
[30] Julius Adolph Stoeckhardt, *Die Schule der Chemie oder erster Unterricht in der Chemie, versinnlicht durch einfache Experimente: zum Schulgebrauch und zur Selbstbelehrung, insbesondere fuer angehende Apotheker, Landwirthe, Gewerbetreibende etc.* (Braunschweig: Vieweg, 1881), 515 (this is the last edition made by St.)
[31] Personal communication Otto Wienhaus.
[32] Tönjes de Vries, "Der Eiskocher", *Chemkon* 9 (2002) 4: 199-200.
[33] Stoeckhardt, *Schule der Chemie* (Braunschweig: Vieweg, 1847), 3d edition, 403-405.
[34] Emil Postel, *Laienchemie oder Leichtfassliche, an einfache Versuche geknuepfte Darstellung der Hauptlehren der Chemie* (Langensalza: Schulbuchhandlung, 1857).
[35] Wilhelm Ostwald, *Die Schule der Chemie* (Braunschweig: Friedrich Vieweg und Sohn, 1903).
[36] For example the following papers of Wilhelm Ostwald, *Die Forderung des Tages* (Leipzig: Akadem. Verlagsgesellschaft, 1910); *Naturwissenschaftliche Forderungen zur Mittelschulreform* (Wien: Manz, 1908); "Die heutige Schule im Widerspruch zur Wissenschaft und zum Leben", *Blaetter fuer deutsche Erziehung* 11(1909) 5: 67-75; "Diskussionsbeitrag zum Biologieunterricht an hoeheren Schulen", *Verhandlungen der GDNAE* (1904), part 1: 155-56; A very good overview you can get from the letters of A.v. Baeyer, R. Abegg and W. Ostwald (Regine Zott, *Gelehrte im Fuer und Wider* (Muenster: LIT, 2002). Compare also: James Altena, Klaus Hansel (ed.), "Wilhelm Ostwald Gesamtschriftenverzeichnis Band 1", *Mitteilungen der Wilhelm-Ostwald-Gesellschaft zu Großbothen e.V.* (2003) Sonderheft 14; Konrad Krause, Ulf Messow, *Wilhelm Ostwald – sein Wirken als Hochschullehrer und seine Auffassungen zur Ausbildung von Chemikern, zum Hochschulunterricht und zum Erziehungswesen* (Leipzig: Karl-Marx-Universitaet, 1983); Regine Zott, "Liebig und Ostwald, Praktiker und Theoretiker von Chemiebildung", *Chemie in der Schule* 37 (1990): 369-374.
[37] Wilhelm Ostwald, *Lebenslinien* (Berlin: Klasing&Co., 1933), vol. I, 169.
[38] Biographical data: Universitaetsarchiv Leipzig, Personalakte Julius Wagner, PA 1025, f. 2; Wilhelm Boettger, "Julius Wagner", *Zeitschrift fuer angewandte Chemie* 38 (1925): 309-310; Gisela Boeck, "Julius Wagner Deutschlands erster Professor fuer Didaktik der Chemie", *GDCh, Fachgruppe Geschichte der Chemie, Mitteilungen* 19 (2007): 169-183.
[39] Julius Wagner, *Ueber den Anfangsunterricht in der Chemie* (Leipzig: Barth, 1903).
[40] Wagner, *Ueber den Anfangsunterricht,* 23-24.
[41] Julius Wagner, "Ueber den chemischen Unterricht an hoeheren Schulen", in *Beitraege zur Frage des naturwissenschaftlichen Unterrichts an den hoeheren Schulen*, ed. Max Verworn (Jena: Gustav Fischer, 1904): 47-69.