The Discourse of Chemistry (and Beyond)

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Abstract: This paper discusses the mainstream discourse of chemistry and suggests a complementary discourse. On a disciplinary level, the discourse of chemistry is based on objectivism, rationalism, and molecular reductionism. On a societal level, the discourse is based on modernism. The aims of chemical research and education are often unclear, which nowadays often leads to an emphasis on the needs from industry. Integrating meta-perspectives (philosophical, historical, and socio-cultural) within chemical research and education practice would – apart from providing chemical *Bildung* to practitioners – also improve the image of chemistry, and in the long run create a more reflective and problematizing discourse.

Keywords: *discourse of chemistry, nature and culture of chemistry, objectivism, modernism, chemical Bildung.*

Introduction

This paper discusses the mainstream discourse of chemistry and suggests a complementary discourse which could complement and to some extent replace the prevailing modernist and reductionist chemistry discourse with a more holistic one.[1] Such a new discourse would emphasize the role of chemistry as a cultural activity within the broader cultural context.

By 'discourse of chemistry' I mean the philosophical and political worldviews and values (both explicit and implicit) by chemists. Such a discourse can be described as a broad societal and historically based flow of ideas that dominate the conceptions and practices of people without being necessarily aware of its influence. Education informs disciplinary discourses.

According to Hård and Jamison (2005, p. 39), modern science at a discursive level "is a set of worldview assumptions, or beliefs, […] that can be depicted schematically" as quantitative ("the measure of reality"), experimental, instrumental, systematic, objectifying, reductionist ("one-dimensional thought"), and futuristic. Of course different chemical sub-disciplines differ in their specific discourses. However, in general the chemical discourse on a

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societal level is based on the modernistic discourse, *i.e.*, the idea that science generates constant progress and improvements for modern society (Liedman 1997).

Due to the practical roots of chemistry, the discourse of chemistry is also based on pragmatism (Kovac 2001). However, the aims of chemical research are not always clear. In a *Mode 2* context (techno-science instead of traditional discipline-based science, see Gibbons *et al*. 1994), this leads to an emphasis on the needs from industry rather than on what is useful to the public and civil society. To make this transparent, it is important to point out the values and assumptions made by the chemical community and its surroundings.

In the following I will first briefly discuss the nature and culture of chemistry. Thereafter, I will give examples from the mainstream discourse of chemistry, followed by a discussion of the complementary discourse. I have chosen to divide the mainstream discourse of chemistry into two levels: *disciplinary* and *societal*. Although not exclusive, the disciplinary level is about the chemists' view of their science as such and how chemical knowledge is understood by the public, whereas the societal level is about the chemists' view of their own role and that of their discipline within society. Table 1 summarizes the main arguments in this paper which is divided into four parts: (1) the nature and culture of chemistry; (2) the discourse of chemistry on a disciplinary level; (3) the discourse of chemistry on a societal level; and (4) the complementary reflective discourse of chemistry.

Table 1. Nature, culture, and the discourse of chemistry

(1) Nature and Culture of Chemistry	(2) Discourse on a Disciplinary Level	(3) Discourse on a Societal Level	(4) Complementary Reflective Discourse
Molecular level	Objectivism	Modernism	Meta-perspectives
Manipulation of matter	Molecular reductionism	Self-image of chemists: 'the central, useful and creative science'	Reflection
Pragmatism	Rationalism: view of the public as 'chemophobic'	Unclear aim	Problematization
Sub-disciplinary fragmentation		Industry emphasis	*Chemical* Bildung

As previously mentioned, education is important in forming disciplinary discourses. Therefore, a discussion of the discourse of chemistry must include chemistry education, both as a research area to take examples from and as a practice to change when striving beyond the current mainstream discourse of chemistry.

1. The Nature and Culture of Chemistry

The core of chemical theory is the dynamics and structure of matter on a molecular level. According to Nye (1993, p. 30) "it is appropriate to emphasize the molecule as the heart of the chemists' problem-solving concerns." Unlike physicists, chemists are not only interested in the general properties of molecules, but also in "the multifunctionality of the chemical molecule's character and behavior and in its capacity for generating wholly new objects".

Because of this capacity to synthesize new molecules and structures it is interesting to discuss whether chemistry is a science or a technology. Schummer (1999) writes, "all received concepts to distinguish between science and technology fail, if we try to apply them to chemistry". I think that chemistry is both a technology and a science, but perhaps more the former. My argument is that chemistry – in addition to its many application areas such as in chemical engineering, biotechnology, pharmaceutics, and food technology – also has a laboratory core that is 'technological'. Much chemistry is about the manipulation of matter on a molecular level. Chemists try not only to understand and explain but also to change the world. According to Schummer (2001), "the scientific products of synthetic chemistry are not only ideas but also new substances that change our material world, for the benefit or harm of living beings". This capacity of chemistry to change the material world has had significant consequences, both positive and negative, on the relationship between chemistry and society.

Chemistry is by its nature a practical science, mirrored in a closely connected industry. Kovac writes:

> Chemists historically have been less concerned with probing the deep secrets of the universe than with the synthesis of new compounds. Chemists make fertilizers and fibers. Chemistry is closer to experiment than physics; chemists must 'think with their hands' more than most other scientists. [Kovac 2002, p. 164]

Nye (1993, p. 4) argues that the disciplinary identity of the early chemistry "lay in its general recognition as an art of laboratory practice useful in medicine, industry, manufacturers, and agriculture". Chemistry was more than natural philosophy or physics of immediate interest to entrepreneurial activities.

The existence of an own industry since a long time ago distinguishes chemistry from other sciences. The symbiosis between the science and the industry has been important to both chemistry and the chemical industry. According to Aftalion (2001, p. xxi) "chemistry cannot be dissociated from the chemical industry which is its twin". Similarly, Laszlo writes:[2] "During the second half of the twentieth century, the self-image of the chemical profession was determined to a large extent by a symbiotic relationship between the science and the industry."

Both the fragmentation of the discipline into a large number of subdisciplines and the disappearing boundaries to other classical disciplines are characteristic of modern chemistry (Sjöström 2006a). Reinhardt (2001, p. 3) express this as: "In the twentieth century, the mushrooming of inter- or transdisciplinary fields labeled with the suffix chemistry indicate that the majority of chemists were involved in activities which belonged to the territory of several disciplines."

Chemistry as an 'umbrella' concept is today so large and full of nuances that nobody can follow the whole research front. According to Schummer,

> to be up-to-date in all areas of chemistry you would currently [1998] have to read about 2,000 new publications every day […] Of course, nobody is capable to read all publications of chemistry, not even all publications of a small area. [Schummer 1999]
>
> To talk of 'chemistry' as a somehow united field seems to obscure the plurality of historical traditions, methods, and scientific aims of this field, as well as the varieties of interdisciplinary projects chemists are and have been working on. [Schummer 1998, p. 129-130]

The fragmentation of chemistry can also be seen in the practical work in chemical laboratories. In a book about academic cultures, Becher and Trowler (2001, p. 188) write about the chemical culture with quotations from chemists:

> chemists have 'many shared assumptions, and a common basis in the study of molecules', but it is 'hard to think of it as a unified discipline'. Chemists 'tend to cut each other down', and 'slanging is more common among chemists than among other scientists': 'When under attack, chemists draw their wagons into a circle, and then start firing into the middle. People tend to be highly critical of each other, rather than supportive. They don't hang together, because the field itself is so fragmented'.

2. The Discourse of Chemistry on a Disciplinary Level

On a disciplinary level the discourse of chemistry is based on objectivism, molecular reductionism, and rationalism. These views are important parts of the nature of chemistry, but become problematic when chemical researchers and educators are not open to philosophical reflection.

Objectivism stands for the view that scientific facts are independent of the context in which they are observed. Most scientists (including chemists) and many modern philosophers of science see nature as objective and real. In contrast, post-modern thinkers view scientific facts as constructed, relative, and context-dependent (Good and Shymansky 2001). Scerri (2003a), a philosopher of chemistry, is very critical of the position of many chemical educators in this "science wars" debate between realism and relativism. He writes:

> The claim of constructivists is that scientific knowledge is somehow socially constructed rather than being discovered. The dominant school of chemical education may [...] be on the wrong side of the recent and notorious Science Wars debate. Some chemical educators have even fallen prey to the related post-modern position of relativism without realizing that this is both self-defeating and essentially anti-scientific in spirit. [Scerri 2003b, p. 8]

Although extreme relativism should be criticized, I would argue that Scerri's position is also extreme in that it is objectivistic in an unreflective way. As Taber writes:

> There are positions between the extremes of (a) 'everything goes' and magic and science are just different ways of seeing the world, and that (b) there is an absolute reality that science is increasingly mapping in perfect detail. [Taber 2003, p. 107]

Another problem with the discourse of chemistry on the disciplinary level is that "chemistry, by its culture, has been almost blindly reductionist." (Whitesides 2004, p. 3634) According to Earley, today's chemistry conveys an atomistic and mechanistic worldview:

> Mechanics (in its classical, quantum, and statistical versions) can rationalize all sorts of interesting things – even aspects of biology. The take-home message [... is] that *submicroscopic components of things are what is ultimately important*. [Earley 2004, p. 144]

From the implicit message that the parts are more important than the total picture many students ignore chemistry "and turn their attention to matters likely to have more importance for their lives". The 1981 Nobel Prize winner in chemistry, Roald Hoffmann, writes:

> Scientists have brought the reductionist mode of thinking as their guiding ideology. Yet this philosophy bears so little relationship to the reality within which scientists themselves operate. And it carries potential danger to the discourse of scientists with the rest of society. [Hoffmann 1995, p. 19]

Rationalism stands for a view of scientific knowledge and methods as free of values. According to Schummer (1997), the rationalist view of chemists makes the dialogue with the public difficult: "The main barrier of ecological dialogue between chemists and the public is the exclusive claim for rationality as part of the professional ethics of chemists." Politically the rationalist view is often connected to the opinion that scientific experts should be given increased political influence.

Many chemistry teachers and chemists – especially those who in some way are connected to the chemical industry – have a nonchalant attitude to the public's fear of chemicals. They think that the public is 'chemophobic'. The following typical statement is taken from a conference on chemical education:[3]

> People blame 'chemicals' for causing some issues such as water quality, air pollution, and herbicides, *etc.* Although life is made of chemicals and human life cannot sustain itself without chemicals, most of the public are unaware of the importance of chemicals and chemistry.

A similar statement is taken from a preface by the Director of the Swedish Plastics & Chemicals Federation:[4]

> You should know that chemicals in some form […] are present in almost all products that […] surround you. The human being consists of many different 'chemical factories' and chemical processes go on continuously as a part of our daily life. […] Actually Sweden and the rest of the world would stop if there were no chemicals. […] Basically there is no big difference between products from nature and those that are produced synthetically. The same […] risks are present everywhere.

In both statements it is clear that the view on the public is affected by a modernistic view of the role of chemistry in society. This will be discussed in more detail in the following section.

3. The Discourse of Chemistry on a Societal Level

The former president of the American Chemical Society, Ronald Breslow (1998), has called chemistry "the Central, Useful, and Creative Science". He thinks that it is central because of its boundaries to both physics and biology and useful because of its importance for technology and medicine. It is also a creative science due to the possibilities to synthesize new compounds and structures. Considering the usefulness of chemistry to the society, Breslow (p. 189) writes: "We chemists extend the natural world all the time, with tremendous effect". However, the quotation can also be used to describe the other face of chemistry, the 'chemicalization' of our environment (Casper 2003).

Chemists frequently have a very positive view of the role of chemistry in the development of society. This is illustrated by the following quotation:

> Chemistry has had a wonderful period of two centuries in which it revolutionized the understanding and manipulation of the physical world: it revealed the atomic and molecular structure of matter, and provided physical things – drugs, clothing, fuels, weapons, materials – that changed society. [Whitesides 2004, p. 3633-4]

Along similar lines, the Royal Swedish Academy of Engineering Sciences argues:

> Chemistry and chemical engineering have had a big impact on the development of the modern society of today. It is true for all areas of application from the industry's production to the daily life of humans. Also in the future chemistry and its applications will have a large and probably vital influence on the development. [Ingenjörsvetenskapsakademien 1993, p. 48; my translation]

The progress optimism of most chemists is further exemplified by the following quotation from the 1994 chemistry Nobel Prize winner, George Olah. Probably unaware of the notion of "the risk society" by sociologist Ulrich Beck (1992), he writes about the energy issue:

> In the laboratory, we already know how to convert carbon dioxide back into hydrocarbons through chemistry using hydrogen gas, H_2. […] The limiting step […] is the electricity needed for generating hydrogen from water. Atomic power plants, *albeit* improved and made safe, will eventually give us needed cheap energy. [Olah 1998, p. 40]

The approach is that the problems caused by science in society can be solved only by even more science.

The basic values of chemistry are connected to its aims and goals. These are rarely discussed in-depth or even explicitly expressed within the chemical community, which can cause problems for the disciplinary identity. Therefore, Schummer (1999) argues for an explicit aim discourse of chemistry and thinks that without it chemistry is in risk of losing its autonomy as a science. Without explicit aims, a science can be easily influenced by external interests. Furthermore, the public and potential students receive an unclear image of the science. Schummer writes:

> From the point of view of philosophy of science, it is extremely difficult to understand what chemistry is all about. […] *The main difficulties in understanding chemistry arise from the fact that we* […] *have no clear idea about the aims of chemistry.* [Schummer 1999]

However, I think that the main aims of academic chemistry today – in the general societal discourse – are to support innovations and to educate students for research and engineering tasks in industry. The latter can be exemplified by the following quotations from the Royal Swedish Academy of Engineering Sciences:

> The goals of chemistry education is to create high competence and to educate a small group of experts, as well as to create awareness and understanding by the broader public of how important and useful the products of the chemical industry are. [Ingenjörsvetenskapsakademien 1993, p. 30; my translation]

Chemistry "education shall […] mainly create problem-solving generalists for the needs of the industry." (Ibid., p. 72; my translation). A similar position is expressed by chemistry educator Wallace (2003, p. 90): "We must turn […] to the needs of the ultimate consumers of universities' products: industry and commerce." There is no emphasis in these quotations on other possible goals for chemistry, such as to provide a broader understanding of the surrounding world or to support the foundation of a democratic society.

The Internet presentation of the Center of Chemistry and Chemical Engineering at Lund University, Sweden, also emphasizes academic curiosity – in addition to the benefits to society – as an aim of chemical research:[5]

> Why do we do research in chemistry? One standard answer is that chemical knowledge is an important base for our welfare. By increasing and improving this knowledge, progress and employment is created. If we instead ask an individual chemist […] he answers that it is extremely interesting to do research. To see a reaction that nobody have seen before, or to calculate a new relationship, is the most exciting you can do in life!

In addition to usefulness, which was emphasized in the earlier quotations, the homepage mentions the intrinsic value of research as one of the aims of the chemical research practice. The last argument is typical of *Mode 1*-thinking, whereas the instrumental usefulness argument is typical of *Mode 2*-thinking (Gibbons et al. 1994).

4. A Complementary Reflective Discourse of Chemistry

In the current (often implicit) discourse on the aims of chemistry a "*Mode 3*-thinking" (Fuller 2002, p. 221) is missing, *i.e.*, an emphasis on what is useful to the public and civil society. In such a research and education discourse, the focus would be on 'enlightening' chemical knowledge with the aim of presenting radical solutions to existing (environmental and social) problems and/or new problems beyond the agenda of the (industrial) establishment. The fundamental aim of chemistry would then be beyond both looking for the secrets of nature (*Mode 1*) and solving problems for the industry or the state (*Mode 2*); instead the aim would be to contribute to the understanding of such things that are important in a functioning democracy, to identify the state of things that are unsatisfactory, and to find solutions on global issues (*Mode 3*). Important chemistry related research areas from a *Mode 3* perspective include, for instance, medicinal chemistry not driven by the market, environmental chemistry, and 'meta-chemical' research areas such as Green Chemistry and Chemistry Education. Today, critical opinions of *Mode 2* thinking – which could result in *Mode 3* research – are often excluded from the chemical research environments (Sjöström 2006b).

Böschen et al. (2003) argue for increased transparency of chemical research and formulate two requirements for "sustainable chemistry": "(1) the assumptions, objectives and implications of chemical research and its technical application should be made more transparent to various social actors [and] (2) uncertainty and ignorance should be treated more explicitly in the course of scientific research." However, this would have consequences for the current view held by the chemical society:

> Establishing a more explicit and mutual relationship between scientific work and societal needs and values requires the epistemological assumptions of chemistry as a natural science to be rethought because, traditionally, the natural science do not have 'interfaces' for this kind of interaction with stakeholder groups and for reconciling non-scientific, for example ethical, values and scientific objectives. [Böschen et al. 2003, p. 94]

In an ethnological study of a university institution dealing with chemistry, Berg (2002, p. 90; my translation) writes:

> The institution […] makes research and educates in subjects that are part of historically legitimized science ideals and cultures. These ideals and cultures grow among representatives of a positivistic science tradition, a tradition that is based on the idea that it is possible to obtain completely objective truths. The attitude to science can be seen as part of the actors' identity within the discipline. Research and education activities are not seen as part of a social and cultural context, and it is uncommon to perform broader reflections on the own production of knowledge.

To some extent I agree with Berg, but I also think that many chemists have tried to see their activities in a social context. However, this view is usually from a technical-instrumental perspective only, from which chemists rarely develop a critical view on the role of chemistry and chemists in society. For example all chemists might ask themselves what personal responsibility they have for the 'chemicalization' in society. Until relatively recently chemists and the chemical industry have to a large extent ignored environmental impacts of their activities. As Woodhouse (2003, p. 193) put it, we need "sensible experimentation, where knowledge is placed in the service of wisdom more than in the service of the ends favored by twentieth-century brown chemistry". The concepts of green and sustainable chemistry can be useful in guiding the practitioners of chemistry to a more responsible practice (Sjöström 2006c).

Like Berg, the chemist Brandt (2003) thinks that the chemical discipline is close to the positivist ideal of a value-free science. However, he claims that chemistry beyond positivism is possible and writes:

> Going beyond positivism [...] means connecting to the wider cultural context, the realm of values, meanings, and purpose, and being concerned, more than before, for example about the image of chemistry, the challenges chemists face as citizens, and the problems and opportunities chemists may find in liberal education. [Brandt 2003, p. 342]

A university course on 'Perspectives on Chemistry' would improve the currently often too reductionist and positivistic chemical education and make it clear to the students that chemical research is not a value free activity. Such a course should cover what I call 'meta-chemistry', *i.e.*, Philosophy of Chemistry, Chemistry Education, History of Chemistry, Chemistry & Society, and Green Chemistry (Sjöström 2006a). In addition to such a university course, there is a need for more meta-perspectives in all chemistry education. Two main perspectives that would complement the subject focus are 'chemistry as culture' and 'chemistry within culture'. The chemist Bunnett (1999) has already – although from a quite strict disciplinary perspective – suggested a PhD course on 'The Culture of Chemistry':

> Besides breath in the core of chemistry [...] the well-educated chemist need [...] what I [...] call the *cortex* of our discipline. By the cortex, I mean bodies of knowledge and thought that illuminate the context within which chemistry is pursued. These include the history and philosophy of science in general and chemistry in particular, the social and political contexts of chemistry [...], the organizational structure of higher education and of scientific research [...], and questions of ethics and values in science. [Bunnett 1988, p. 775]

In a paper about future chemistry education on the university level, Krageskov Eriksen (2002) argues – more systematically than Bunnett – for the need of three kinds of knowledge in chemical education: (1) "ontological" chemical knowledge, *i.e.*, real chemistry; (2) "epistemological" knowledge, *i.e.* philosophical and sociological perspectives on the chemical practice; and (3) "ethical" knowledge, *i.e.*, reflection on the role of chemistry in society. These three kinds of knowledge are needed to educate reflecting chemists, which are needed in the 'risk society'.

> Traditionally, much chemistry teaching at the university level has primarily been linked to the ontological knowledge sphere of chemistry, carrying with it a tendency to treat the subject of chemistry as a collection of factual information that should be learned as well as possible. [...] If a *Bildung* focus [...] is adapted as a perspective on education, the awareness of all three spheres of

> chemical knowledge must be raised to explicate and open the 'rules of the chemistry game' for reflection and debate. [Eriksen 2002]

What do we mean by *Bildung*?[6] For our risk society in the age of 'supercomplexity', I have suggested a *Bildung* ideal with three legs (Sjöström 2006d). These three legs are (1) a holistic view, or broad knowledge and multiperspectives; (2) wisdom, or a critical and ideologically reflective approach; and (3) *phronesis* (practical wisdom), or the ability to put into practice the personal ideology as well-reasoned and responsible actions. The first leg is about 'intelligence' with time, space, and culture as the three basic perspectives needed to understand our world. The second leg is the personal liberation project; it is about maturing as a human being towards wisdom as a state when the thinking of a person integrates worldviews, values, and scientific knowledge. Finally, the third leg is about practical wisdom, or *phronesis*, a term borrowed from Aristotle.

Bildung is closely related to 'soft enlightenment' which, in contrast to 'hard enlightenment' and its emphasis on knowledge for productivity, emphasizes well-spread, broad, and value-oriented knowledge. According to Liedman, the society today mainly focuses on hard enlightenment, which is connected to the progress optimism of modernity (Liedman 1997). However, post-modern thinking, which is common for individuals with a high degree of *Bildung*, results in critical reflection on modernity and its different shapes of progress optimism (Liedman 2001).

All three legs in my suggested *Bildung* ideal are needed to be able to reflect on important societal questions in a critical, balanced, and user-oriented way. Such societal questions may address the interplays between science and society, and between economy and ecology. Those questions have in common that they need perspectives from science as well as from the humanities.

With regard to environmental and sustainability issues there have been calls for more societal and ethical perspectives in the education of chemists. Jastroff thinks that a "chemist's literacy" should consists of both "disciplinary skills" and "complementary skills", which includes the ability to think and act in the spirit of the UN Agenda 21.[7] Similarly, Zoller (2004) claims that "environmental literacy requires the integration of environmental sciences into core chemical courses" and that there is an ongoing process from "specialized, compartmentalized, and disciplinary, into multidimensional, cross-boundary endeavor in the science-technology-environment-society (STES) interfaces".

Bildung is needed if we want transparent, reflective, and responsible research environments. With more knowledge about STES, scientific researchers can increase their socio-scientific orientation and their critical awareness of ideologies. The research environments would then probably become more welcoming for a broad spectrum of personal backgrounds and ideologies, unlike the current exclusion of free- and alternative-thinking individuals, which could promote creative and responsible innovations.

Finally, integrating meta-perspectives (philosophical, historical, and socio-cultural) in the chemical research and education practice would not only provide chemical *Bildung* to practioners; it could also improve the currently too rationalist and reductionist public image of chemistry, and in the long term create a more reflective discourse of chemistry.

I conclude with a quotation from gender studies professor Relke (2002):

> The difference between technical knowledge and wisdom is the difference between, on the one hand, someone who has mastered the theories, methodologies, and techniques required to practise science and, on the other, the true professional, who also understands these things in the context of the history, philosophy, sociology and political economy of science – in short, the science of the sciences.

Notes

[1] The author has a Ph.D. degree in chemistry.

[2] Pierre Laszlo, 'On the Self-Image of Chemists, 1950-2000', abstract to the conference *Public Images of Chemistry in the Twentieth Century*, Paris, September 17-18, 2004. See also Laszlo 2006.

[3] Choon H. Do and Jung-Il Jin, Korea, 'Public's perception of chemistry', oral presentation at the *18th International Conference on Chemical Education – Chemistry Education For the Modern World*, Turkey, August 2004, p. 90 in the abstract book.

[4] From the brochure: Kemikontoret: 2000 'Den matnyttiga kemin', p. 5, preface by Owe Fredholm (my translation).

[5] See www.kc.lu.se/Safari/default.htm (last up-dated: 4 Feb. 1999; fetched 28 April 2005) (my translation).

[6] 'Bildung' is the German term for a pedagogical concept, for which there is no precise English translation (Vásquez-Levy 2002). However, it is sometimes translated to English as 'liberal education' and/or 'cultivation'. In Swedish it is known as 'bildning'. For a deeper discussion in Swedish see Gustavsson 1996.

[7] Bernt Jastroff, 'University's responsibility: Sustainable Development as a literacy in chemist's education', presentation at the international workshop *Sustainable Chemistry*, Dessau, Germany, January 27-29, 2004.

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This paper discusses the mainstream discourse of chemistry and suggests a complementary discourse. On a disciplinary level, the discourse of chemistry is based on objectivism, rationalism, and molecular reductionism. On a societal level, the discourse is b...Â The aims of chemical research and education are often unclear, which nowadays often leads to an emphasis on the needs from industry. Integrating meta-perspectives (philosophical, historical, and socio-cultural) within chemical research and education practice would â€“ apart from providing chemical Bildung to practitioners â€“ also improve the image of chemistry, and in the long run create a more reflective and problematizing discourse.