The Future of Tertiary Chemical Education – A *Bildung* Focus?

Kathrine Krageskov Eriksen

Abstract: In this study the concept of *Bildung* as an aim for tertiary chemical education is discussed, particularly seen in the light of the challenges of society as they can be identified in Ulrich Beck's perspective on the emerging society as a 'risk society'. The importance of reflectivity as part of contemporary *Bildung* is highlighted, and the role of ethics in this reflectivity is specifically discussed.

Keywords: *ethics*, *tertiary chemical education*, *Bildung*, *risk society*, *reflectivity*.

1. Introduction

In this study I will contribute to the topic of 'Ethics and Chemistry' by considering tertiary chemical education in a social perspective and the role of ethics within this context. More specifically, I will consider the concept of *Bildung*[1] as a useful tool for structuring discussions on tertiary education within the chemical/scientific sphere, and I will argue that reflectivity must be included in a contemporary *Bildung* ideal.

Hence not only the relationship between ethics and chemistry, but also the role of university chemical education in contemporary society and the *Bildung* concept need to be discussed. I will therefore begin by considering the demands the worlds of today and tomorrow put on the chemical graduates and the implications this might have for the development of university education. I then go on to introduce my interpretation of a contemporary *Bildung* concept, hereby presenting reflectivity as a crucial component of an adequate *Bildung* of chemists. Finally, I will discuss the *Bildung* concept sketched as a possible answer to the demands drawn up in the first section – and in doing this I will be considering the exact nature of the reflectivity, including the role of ethics, needed to make *Bildung* a valid answer to these demands.

HYLE – International Journal for Philosophy of Chemistry, Vol. 8 (2002), No. 1, 35-48.

2. Universities of Today and Tomorrow

To discuss tertiary chemical education in an ethics perspective, we first need to consider the role of this education in society. What is the purpose of it? The Danish university law[2] states that institutions of higher education have as their dual purpose to do research and to offer higher education, both meeting the highest scientific standards. An example of a contemporary interpretation of this object clause can be found in the official plan for the development of the University of Copenhagen for the years 2000-2003:

> The University graduates shall through their studies achieve the highest possible professional and personal competence, so that the graduates can enter into society with qualifications meeting the demands of this society and contributing to the further development of this latter. [University of Copenhagen 2000, p. 5; my translation]

Currently, the University of Copenhagen thus seems to define its identity as closely linked to the need of society for highly educated members. Other perspectives on, and thereby aims for, higher education can of course be expressed. When explicated, this would include the interest of the academic community in recruiting new members, the students' interest in self-fulfillment, and the need of the labor market for skilled employees[3] (Simonsen & Ulriksen 1998).

I choose, however, in my discussion of universities of today and tomorrow to focus on the angle of society. The use of this perspective will bring forward a discussion of the role of chemistry and chemists in present society which, from my point of view, is absolutely imperative when the topic of chemical education and ethics is on the agenda. Consequently, the questions are: What are the demands that society puts on chemical graduates? And how can the chemical graduates contribute to society's further development? To answer these questions we first have to clarify what this society looks like, particularly what the societal role for chemistry (and science in general) is.

Designations for the society emerging (the post-modern, the post industrial, the knowledge, or the communication society are examples) are abundant. As a consequence of this we may also identify a diversity of opinions on which factors are more important in the development of this society as we are leaving modernity, an era where scientific and technological progress changed the lives of human beings forever. Chemistry and chemically derived technologies have been key actors in the processes marking this era. For example, chemicals created by humans are now used to treat diseases and fight pests that previously destroyed crops and caused famine and death. To illustrate, the chlorinated hydrocarbon dichloro-diphenyl-trichloroethane (DDT) was discovered to be an extremely effective insecticide around 1940. The World Health Organization (WHO) estimates that 25 million lives have been saved due to the use of DDT and other chlorinated hydrocarbons in, for one instance, the fight against the malaria-carrying mosquito (Sherman and Sherman 1992, p. 416). Furthermore, the use of DDT for agricultural purposes resulted in considerably increased yields in the 1950s.[4]

However, as time passed the initial optimism surrounding the potential of DDT faded. The use of DDT and the accumulation of the chemical in the food chain were linked to the decline of various bird and fish populations, strains of insects resistant to the chemical began to evolve and, since some of the natural predators of these pests had been killed off by DDT, the resistant strains prospered (*ibid.*). Recent theories link DDT and other chemicals with hormone-like effects to the declining fertility in the population. Even though today the use of DDT in agriculture is banned in most countries, many developing countries still use the insecticide both for agricultural purposes and (legally) in the fight against diseases. Paired with the long half-life of the chemical in nature this means that relatively high concentrations of DDT can still be found in living organisms all over the world.[4]

The DDT case is an exemplary illustration of the development that is central to the German sociologist Ulrich Beck's (1997a) characterization of the emerging society as a 'risk society'. Beck's analysis captures aspects of contemporary society particularly important when the social roles of technology, science in general, and chemistry in particular are discussed. For the purpose of this study, I therefore choose Beck's societal analysis as a description of imminent challenges to society.

The notion 'risk society' refers to "a stage of radicalized modernity" (Beck 1997b, p. 20), where it is the success of modernity, *e.g.* of the scientific and technological development constituting its hallmark, that produces a new social order. The unintended consequences of modernity, the manufactured uncertainties or risks, not the external risks[5] stemming from nature (such as floods or plagues), become central to the development and the focus of our attention. In the DDT case, the unintended consequences of the (apparent) scientific victory over malaria – the death of fishes and birds, the accumulation of a toxic chemical in the food chain and the possible effects on humans – have become a social issue calling for political action. As Giddens, who also uses the concept of risk as part of his analysis of society, points out, the label 'risk society' does not mean that our age is more dangerous or risky than the world of previous generations; however, the balance has changed so that the risks manufactured by ourselves have become dominant over the external risks or dangers, at least in the rich western societies (Giddens 1999, p. 34).

Chemistry, science in general, and technology are closely linked to the manufacturing of these risks; the risks are the products of the success of science and technology, the unforeseen consequences in one area of society of the (scientific) success in another area. This does not mean that science alone is to blame. It does mean, however, that the processes of modernity will not inevitably bring the solutions to all our problems. Technological improvements will not produce complete answers. As solutions are found, problems penetrating other areas of society are generated.

Beck (1994) distinguishes between two phases of risk society. First, a stage in which the self-threats are produced (*e.g.* DDT is produced and released into the environment without attention to the possible side-effects). And second, a stage when the realization that these self-threats exist begin to dominate the social debates (*e.g.* the realization that DDT is toxic, that it has already accumulated in the environment, and that political action must be taken). Hence, the transition of society into a risk society is an autonomous, undesired development – a social *reflex*. It is the radicalization of modernity – modernity at its extreme, not something beyond or post modernity – "which breaks up the premises and contours of industrial society and opens paths to another modernity" (Beck 1994, p. 3). Beck therefore refers to this transition as *'reflexivity'*, and he introduces the notion *'reflexive modernization'* to describe a society in which the self-confrontation with the self-threats or manufactured risks have become dominant: "[S]ociety becomes reflexive, that is, becomes both an issue and a problem for itself" (Beck 1997b, p. 11). The focus has shifted "from what nature can do to us to what we have done to nature" (Beck 1997b, p. 10). From the danger of catching malaria to the consequences of the scientific fight against malaria.

Despite the apparent hopelessness, Beck does not see society as he characterizes it as heading for a dystopia where our attempts to solve the problems we are facing will inevitably mean that we destroy the world as we know it. Rather, he sees risk society as "a new model for understanding our times, in a not unhopeful spirit" (Beck 1997b, p. 20). The realization that society has changed can open up for new solutions to the problems of the world. Because "nineteenth-century, scientific models of hazard assessment and industrial notions of hazard and safety" (Beck 1997b, p. 17) simply cannot capture the risks of today, we must redefine the way in which we handle these risks. And it is exactly this realization, linked to the second stage of risk society, which may enable us to deal with the challenges of reflexive modernization.

> In the risk society, the recognition of the unpredictability of the threats provoked by techno-industrial development necessitates self-reflection on the foundations of social cohesion and the examination of prevailing conventions and foundations of 'rationality'. [Beck 1994, p. 8]

Beck's analysis tells us that we need to reconsider the established ways of dealing with the world; we need to open up previously depoliticized areas of decision-making for public reflection and debate. This means that the institutions of science and technology, including research agendas and plans for development of new technologies, must be politicized (Beck 1997b, p. 21).

To further investigate the consequences of this demand we need to consider the meaning of the term 'politicization'. Based on the analyses by Arendt (1958), Castoriadis (1995), and Habermas (1999), Straume (2001) describes a society as being political when open, free, and investigative public discussions about the aim and organization of the society are going on – and when the debating public is actually in control of the society. Politicization thus means that the purposes, laws, norms, institutions, and, not least, the institutionalizing practices of society are open for reflection. To summarize, "a society can be said to be political to the degree that it is reflective" (Straume 2001).[6] The term 'reflective' is here used to designate both a reflection and the action for change of the practices, *i.e.* an active transformation. Below, I will refer to this process as *'reflectivity'*. Consequently, Beck's call for a politicization of all decision-making arenas to meet the challenges of reflexive modernization can also be expressed as a call for (increased) reflectivity linked to the decision-making processes in these forums, including science and technology. In other words, to deal with reflexive modernization, we need reflectivity!

Beck offers a concrete interpretation of the constitution of such a reflective society. He characterizes it as a technical democracy, that is, a responsible society that debates the consequences of a certain development, *e.g.* technological, before implementing it (Beck 1997b, p. 21). Beck suggests as a concrete place for this reflection "forms and forums of consensus-building co-operation among industry, politics, science and the populace" (Beck, 1994, p. 29). A rudimentary form of such forums can be found already in ethics committees, where the paths of scientific research are being debated: Should we or should we not accept the cloning of human embryos, to take a topic currently being discussed in many countries. The important attribute of the forums is the diversity of opinions and interests, since a single focus on the world, *e.g.* scientific, will – to use a concept from Sandra Harding (2000) – create "distinct patterns of systematic knowledge and its ever-present companion, systematic ignorance". The idea is that the various groups represented should supplement each other. It is exactly this meeting between the different ways of seeing the world that, in Beck's opinion, is central. Only by negotiating several aspects of the paths we are choosing can we ensure that the development in the future will be more environmentally and socially robust.[7]

Even if one does not fully accept Beck's idea of negotiation forums, many challenges call for public reflectivity. Scientists, including chemists, who are open to other viewpoints, not know-all experts, are needed in this public debate. Hence – to return to the role of university education in relation to the needs of society – we find a demand for educational institutions recognizing this call for reflectivity in the education offered to their students, the scientists of tomorrow. To prepare the analysis of the consequences for chemical education that might be drawn from this demand, I will in the following part introduce the pedagogical concept of *Bildung*. This concept can, so I believe, act as an important guideline in the discussion of what the practical implications would be for chemical university education if the demands for increased reflectivity were met.

However, before opening this discussion, I will present a brief historical introduction to the *Bildung* concept as well as my proposal for a contemporary interpretation of this concept in a university chemistry context.

3. A Contemporary *Bildung* Ideal

Words for the same concept can be found as 'Bildung' in German, 'bildning' in Swedish, or 'dannelse' in Danish and Norwegian. When directly translated, the term refers to the formation or shaping of an individual (into 'an educated person'). *Bildung* as a pedagogical concept implies that students must develop personally somehow – mature – through their education, not just learn some specific vocational skills. However, over time various *Bildung* ideals – *i.e.* the ideal according to which the student should be formed – have been expressed (*e.g.* Madsen *et al*. 1993).

The concept of *Bildung* is rooted in medieval Germany where it implied the formation of a person in the image of God (Abrahamsson *et al*. 1988). In the 18th century the German bourgeoisie adopted the concept now formed to strengthen the bourgeois identity; as a *gebildet* (or, educated) person you could, even without a noble birth, still be valuable (*ibid.*). Probably inspired by this German *Bildung* 'trend', around 1800 the term obtained a footing in Scandinavia as an educational concept. At that time it contained ideas about a classical education and the shaping of the individual, to which studies of traditional disciplines like Latin and Greek were thought to be conducive (Laursen 1994). In recent years the concept in a modern version has regained a place in the Scandinavian educational discourse (Schnack 1994), and it has now come to imply the shaping of the individual into a responsible democratic citizen. Also, in a science education context, *Bildung* has entered the stage (Sjøberg 1998) and ideas somewhat similar to Sjøberg's modern *Bildung* concept are underlying contemporary science education trends like STS (science-technology-society) education, science taught as a liberal art, and education for scientific literacy.

Different approaches to a contemporary use of the *Bildung* concept can be identified in the educational debate, and one of the most influential interpreters of a modern *Bildung* ideal has been the German pedagogue Wolfgang

Klafki (Troelsen 2000). As a starting point for my development of a contemporary *Bildung* concept, I will, however, take the study "Socialization and Technocracy" by the Norwegian philosopher Jon Hellesnes (1976), which I find introduces a distinction still useful when *Bildung* is on the agenda. In this study Hellesnes analyses the socialization[8] taking place within the educational system in a technocratic society. In doing this, he introduces two main forms of socialization, *Bildung* and 'adaptation' (*ibid*., p. 18). Hellesnes defines 'adaptation' as the unreflective socialization into a system without realizing that 'the rules' can be discussed and changed. Contrasting this, he then defines 'Bildung' also as socialization into a system, but as an open or reflective socialization where this system and its premises are uncovered and discussed. With a *Bildung* perspective guiding the educational planning, students capable of critically considering the premises of the system, 'the rules of the game' – not just skilled players – will be the intent. *Bildung* thus becomes more of a perspective on education than a product (Schnack 1994).

Hellesnes' analysis is rooted in the 1970's and it carries with it an overlying ideal typical of that time of overthrow of the capitalist order. Without subscribing to this ideal, I will adopt the adaptation/'Bildung' distinction from Hellesnes. Although the conditions for socialization in society are not black and white so that the adaptation/*Bildung* dichotomy may be clearly identified in real life socialization processes (Kryger 1994), the conceptual pair can, so I hope to illustrate below, work as a powerful tool in the analysis of educational questions and thus also in the discussion of future tertiary chemical education.

I suggest that a modern ideal for the formation of university chemistry students must be related to the role of their work within society; hence 'the formation to a responsible citizen' can be said to express the *Bildung* ideal I refer to. Further, my interpretation of a contemporary *Bildung* concept applies Hellesnes' dichotomy as a point of departure. To make the concept operative in the concrete context of tertiary chemistry education, it needs further elaboration, however. Socialization processes are dependent on several factors including both the concrete content of education (chemistry) and the way in which the teaching and the educational institutions are organized (Illeris 1999, pp. 91-112). Thus, it is essential to consider (at least) both of these aspects of tertiary chemistry education. Bearing in mind Hellesnes' definition of 'Bildung' as reflective sozialization, I therefore suggest reflectivity in relation to both the content and the organization of the teaching as the focal point for an adequate modern *Bildung*.

To illustrate the meaning of this reflectivity I will again consider the DDT case, this time in a teaching context. Teaching university chemistry students about halogenated organic compounds usually involves an introduction to the spatial structure of the compounds, ways of synthesizing the compounds and concrete examples of compounds from the group, DDT being one example. I will refer to this type of knowledge as 'ontological'[9] chemical knowledge and under this heading include chemistry per se, knowledge about chemical compounds, concepts, and laws.

However, as the DDT case indicates, there are further aspects to chemical knowledge. First, in the teaching of halogenated compounds the historical background to the synthesis of these compounds or perhaps a discussion of the synthesis and testing procedures linked to the development of new chemical compounds could be included. All these aspects are linked to another sphere of the subject of chemistry which I will refer to as the 'epistemological sphere' or the understanding of chemistry as an activity (including theories about the nature of chemical knowledge and the ways in which to arrive at this knowledge) and as a scientific community producing knowledge. Second, as clearly illustrated in the DDT case, the subject of chemistry also consists of a third sphere, which could be referred to as the social or 'ethical sphere' and which contains knowledge of chemistry in a social context including the questions of how chemistry is part of society and which (ethical) considerations should be made in this regard. In the case of halogenated hydrocarbons, a discussion of the use of DDT as an insecticide and the consequences now being linked to this use could be a way to include this third sphere of the subject of chemistry in the actual teaching.

The explicit incorporation of all three spheres of chemical knowledge into tertiary chemical education could help ensure reflectivity at the subject content level – the constant reflection on this content knowledge: What is chemical knowledge? How is it produced? Is it true? How is it used? What are the benefits and dangers connected to this use? Do we as chemists have a responsibility for this use? *Etc.* 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.[10] Hellesnes in his study warns us that such a perspective on teaching can by a seemingly objective and efficient presentation of factual knowledge put the subject matter above discussion. The purely factual approach to problems will reduce them to something external to real life (Hellesnes 1976, p. 209). The consequence is that the students "are socialized into an attitude towards factual knowledge and expertise as morally and politically neutral" (Hellesnes 1976, p. 206) – they become adapted. On the other hand, if a *Bildung* focus as the one outlined here is adopted 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.

This opening also includes reflectivity at the level of organization of the teaching and the educational institutions. Reflectivity concerning the subject matter has to be mirrored in the organization of the teaching. It will not take place if all communication between educators and students take the form of one-way lecturing in large lecture theatres. Universities, other institutions of higher education, and the chemical (scientific) community as such can in many ways be regarded as social institutions or societies (Ziman 2000b, p. 4). Drawing on the definition of politicization introduced above and bearing the conditions of *Bildung* in mind, the possibility for *Bildung* of chemistry students and chemists in general can now be said to be closely linked to the degree of politicization of these societies. This includes the possibility for students to actively engage in discussions about the activities (teaching, research, *etc.*) stemming from the society. Without ongoing reflectivity chemists cannot be *gebildet* – only adapted to the existing norms. Included in the *Bildung* ideal advanced here is thus that we must work for a politicization of the chemical and scientific community and the institutions which educate the future members of this society.

To summarize, my interpretation of a contemporary *Bildung* for tertiary chemical education highlights the importance of reflectivity at two levels; related to both the form and the content of education, and it has as its underlying ideal the vision that chemists should be able to act as social actors also outside a narrow academic context. I therefore see *Bildung* more as a perspective on both education and the chemical/scientific practice which can ensure the awareness of and guide the socialization processes that will inevitably occur, rather than an actual goal which can be reached and measured.

But can that perspective be usefully applied to tertiary science education to meet the demands described in the first section? In the next section, I will try to answer this question. In so doing, I will consider more explicitly – in the concrete teaching context – the exact nature of the reflectivity that I have highlighted as the main component of my concept of *Bildung*, including the role of ethics.

4. *Bildung* as the Answer – What Kind of Reflectivity?

If we reconsider Beck's vision of an adequate answer to the challenges of reflexive modernity, the key word is reflectivity. Reflectivity is needed in the decision-making processes, including the areas of science and technology. Similarly, the focal point for the interpretation of a modern *Bildung* ideal for tertiary chemical education that I offered above is reflectivity – concerning both the subject matter and the 'educational room'. But how can reflectivity as a guideline for the educational planning become part of the answer to a realization of Beck's vision for a reflective society?

The answer is of course closely connected to the way in which the concept of reflectivity is operationalized in the concrete teaching practice. To prepare future chemists for societal reflectivity, reflectivity in the teaching has to include a social angle. As previously highlighted this includes the integration into the teaching of the epistemological and, in particular, the ethical spheres of chemical knowledge. However, a further investigation of this ethical sphere is needed – what exactly does it imply?

Often 'ethics' in a chemistry teaching context is interpreted as 'good scientific conduct'. To illustrate, the ethics training required by the American National Institute of Health (NIH) as part of their training grants is defined as instruction in the responsible conduct of research; instruction in the following areas is stressed: conflict of interest, authorship, misconduct, the use of animal and human research subjects, as well as data management.[11] In contrast to this I previously interpreted the ethical sphere of the subject of chemistry as the understanding of the role of chemical knowledge and the products of this knowledge within society. It is my claim that the former interpretation of ethics in the university chemistry teaching setting is not only inadequate, it can – if the aim is to raise the reflectivity in the sense used here – be decidedly inexpedient. If, in the teaching, the external dimension of scientific ethics – dealing with science in connection to the rest of society – is limited to incidents where the external world is directly used for scientific work, *i.e.* the treatment of human or animal subjects, there is a danger that a scientific self-perception where science is seen as detached from society is conveyed to the students. Conclusively, in the educational setting an interpretation of ethics as 'good chemical conduct' constitutes merely a sort of vocational training – 'learning how to do science right' – instead of a critical approach – 'what is the right thing to do and why?' Contained in this latter is a broadening of the students' world perspective and the ability to see the relatedness of various spheres, including the interwoven nature of the ontological, the epistemological, and the ethical spheres of the subject of chemistry. In other words, enabling the students to comprehend the complexity of reflexive modernization. At its extreme the limited, internal perception of ethics teaching could convey to the students the idea that, when everything is being performed according to the internal ethical guidelines, *i.e.* it constitutes 'good science', then the responsibility of the scientist would be fulfilled. This leaves out the social dimension and as John Ziman points out:

> [T]he scientist who takes a job doing research on Napalm on the grounds that it is 'good chemistry' is almost as much a pervert as the medical researcher who experiments on patients without their informed consent. Doing 'good science' is not synonymous with being a good person. [Ziman 2000a]

And we can add that this view on science is definitely not the answer to the call for increased reflectivity in the 'world' of science.

Rather, the answer must be a broader socially relevant interpretation of ethics. I previously suggested seeing the ethical sphere of the subject of chemistry as knowledge about the relation between chemistry and society. Hence ethical reflection in the context of chemical education comes to mean the reflections on the role of chemistry in society and hence on the values underlying this interplay – and, bearing the ideal of reflectivity in mind, the action for adjustment of the values to the social challenges of today and tomorrow. In an ongoing project designed to raise the level of reflectivity in science teaching in Denmark, we (Hvid *et al*. 2000) have defined ethical reflection as the reflection on the scientific values, both the internal values concerning the way scientific work is carried out and the external values concerning the way science relates to the rest of society.[12] The tools for reflection must be found outside of the 'world' of natural science and can be for example historical, psychological, or sociological analyses of the scientific enterprise. Taking this definition as the starting point, ethical reflection in chemistry teaching can thus be defined as an ongoing reflection – via historical, sociological, *etc.* analyses – on the chemical enterprise and the values governing this endeavor, including the discussion of the adequacy of these values. Are they actually eligible for meeting the role of science in the world of today? *And* how can we change them?

Hence, ethical reflection comes to involve many aspects of chemistry besides traditional ethics. And interpreted in this broader way, ethics as an integrated part of the teaching in chemistry can probably contribute to a raising of the reflectivity, both in the educational setting, in the chemical community, and in society as such.

In conclusion, meeting the demands of society highlighted in the initial statement from the University of Copenhagen can, employing Beck's analytical angle on society, be interpreted as an increased awareness of reflectivity in the university education, thereby preparing the students to engage actively in the reflective social processes. Further, a *Bildung* perspective, as it has been interpreted here, on tertiary chemical education can help guide the educational planning necessary to meet this demand. And finally, increased integration of ethics in teaching can – if a broad understanding of the concept is chosen – be one course to increased reflectivity, both concerning the subject matter, the chemical community, and the role of chemistry within society.

Notes

1 'Bildung' is the German term for a pedagogical concept known as 'bildning' in Swedish and 'dannelse' in Danish and Norwegian. The meaning of the concept, which will be further discussed later, refers to the personal formation of a person.

In the remainder I will, for convenience, refer to the concept by the German term 'Bildung'.

[2] The full text of the University Law can be found at http://www.uvm.dk.

[3] See for example Troelsen 2000 and Eriksen 2001 for a discussion of the interests identified by Simonsen & Ulriksen (1998) and *Bildung*.

[4] See the Resume of the TV program about DDT at http://www.dr.dk/undervisning/mirakelgiften.htm.

[5] I draw on the distinction between two types of risks; external and manufactured as introduced by Giddens (1999, p. 26).

[6] If not otherwise indicated, all translations are mine.

[7] The expression 'socially robust knowledge' is used by Nowotny *et al.* (2001) to designate knowledge that has been debated, i.e. the consequences of a certain development and its implementation in society has been discussed publicly before action is taken. Nowotny *et al.* use the Greek term 'Agora' as a metaphor for the forum where science and 'the public' meet for this discussion – but the idea shows resemblance to Beck's negotiation forums.

[8] Illeris (1999, p. 17) describes socialization, learning, development, and qualification as overlapping processes inevitably linked to any educational activity.

[9] The three spheres of chemical knowledge introduced here are inspired by the division of scientific knowledge into three dimensions in connection with the scientific literacy debate (Sjøberg 1998, pp. 156-57). The designations for the spheres are borrowed from Östman (1999).

[10] The content of most chemical textbooks confirms this claim.

[11] See *The NIH guide*, vol. 23, no. 23, June 17, 1994 at http://grants.nih.gov/grants/guide/notice-files/not94-200.html.

[12] John Ziman (2000a) refers to these values as epistemic values (internal) and moral values (external).

References

Abrahamsson, K. (ed.): 1988, 'Ett samtal om bildningsbegreppets rötter', in: L. Lindström, K. Abrahamsson, *Bildningsbegreppets rötter*, Arbetslivscentrum, Stockholm, pp. 7-31.

Arendt, H.: 1958, *The Human Condition*, University of Chicago Press, Chicago.

Beck, U.: 1994, 'The Reinvention of Politics: Towards a Theory of Reflexive Modernization', in: U. Beck, A. Giddens, S. Lash, *Reflexive Modernization*, Polity Press, Oxford, pp. 1-55.

Beck, U.: 1997a, *Risikosamfundet*, Hans Reitzels Forlag, København [Danish translation of: *Risikogesellschaft. Auf dem Weg in eine andere Moderne*, Suhrkamp, Frankfurt, 1985].

Beck, U.: 1997b, 'The Politics of Risk Society', in: J. Franklin (ed.), *The Politics of Risk Society*, Polity Press, Cambridge, pp. 9-22.

Castoriadis, C.: 1995, *Filosofi, politik, autonomi*, Brutus Östlings Bokförlag Symposion, Stockholm/Stehag.

Eriksen, K.K.: 2001, 'Bildung – a Useful Perspective on Tertiary Chemical Education?', in: R.H. Evans, A.M. Andersen, H. Sørensen (eds.), *Bridging Research Methodology and Research Aims*, The Danish University of Education, Copenhagen, pp. 114-121.

Giddens, A.: 1999, *Runaway World – How Globalisation is Reshaping our Lives*, Profile Books, London.

Habermas, J.: 1999, *Kraften i de bedre argumenter*, ed. Ragnvald Kalleberg, Gyldendal, Oslo.

Harding, S.: 2000, 'Difference, Democracy, and Philosophies of Science', unpublished presentation at the Royal Danish School of Pharmacy, June 2000.

Hellesnes, J.: 1976, *Socialisering og teknokrati*, Gyldendals pædagogiske bibliotek, København [Danish translation of: *Sosialisering og teknokrati: Ein sosialfilosofisk studie med særleg vekt paa pedagogikkens problem*, Gyldendal Norsk Forlag, Oslo, 1975].

Hvid, S.; Nielsen, P.M.; Hansen, T.B. & Eriksen, K.K.: 2000, *Application to the Center for Educational Development in University Science*, Center for Science Education Studies, University of Copenhagen (unpublished).

Illeris, K.: 1999, *Læring*, Roskilde Universitetsforlag, Frederiksberg.

Kryger, N.: 1994, 'Dannelse – og demokrati – eller kampen om hvori det almene består', in: K. Schnack (ed.), *Fagdidaktik og Dannelse – i et demokratisk perspektiv*, Danmarks Lærerhøjskole, København, pp. 75-92.

Laursen, P.F.: 1994, 'Dannelsens genopstandelse', in: K. Schnack (ed.), *Fagdidaktik og Dannelse – i et demokratisk perspektiv*, Danmarks Lærerhøjskole, København, pp. 101-111.

Madsen, V.B.; Jensen, K. & Meldstad, M.: 1993, *Universitet, samfund og dannelse*, Forlaget Sociologi, København.

Nowotny, H.; Scott, P. & Gibbons, H.: 2001, *Re-Thinking Science*, Polity Press, Cambridge.

Östman, L.: 1999, 'Science Education versus Science – Conflicts Within the Academic Setting', unpublished presentation at the 2nd International Conference of E.S.E.R.A, Kiel, Germany.

Schnack, K.: 1994, 'Dannelse som et pædagogisk perspektiv', in: K. Schnack (ed.), *Fagdidaktik og Dannelse – i et demokratisk perspektiv*, Danmarks Lærerhøjskole, København, pp. 93-100.

Sherman, A. & Sherman, S.J.: 1992, *Chemistry and Our Changing World*, Prentice Hall, Englewood Cliffs, New Jersey.

Simonsen, B. & Ulriksen, L.: 1998, *Universitetsstudier i krise*, Roskilde Universitetsforlag, Frederiksberg.

Sjøberg, S.: 1998, *Naturfag som allmendannelse – en kritisk fagdidaktik*, Ad Notam Gyldendal, Oslo.

Straume, I.: 2001, 'Noen krav til en akademisk praksis for samfunnspolitisering', unpublished presentation at Nordic Summer University seminar, Oslo, February 2001.

Troelsen, R.P.: 2000, 'Kompetenceudvikling i kemiuddannelserne', in: T.B. Hansen, K.H. Nielsen, R.P. Troelsen & E. Winther, *Naturvidenskab, dannelse og kompetence*, Aalborg Universitetsforlag, Aalborg, pp. 62-132.

University of Copenhagen: 2000, *Udviklingskontrakt 2000-2003*.

Ziman, J.: 2000a, 'Getting scientists to think about what they are doing', unpublished presentation at the Royal Danish School of Pharmacy, May 2000.

Ziman, J.: 2000b, *Real Science – What it is, and what it means*, Cambridge University Press, Cambridge.

Kathrine Krageskov Eriksen:
Center for Science Education Studies, University of Copenhagen, Universitetsparken 5, DK-2100 Copenhagen, Denmark;
kke@symbion.ki.ku.dk