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Use of the concept of *Bildung* in the international science education literature, its potential, and implications for teaching and learning

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ABSTRACT

Bildung is a complex educational concept that emerged in Germany in the mid eighteenth century. Especially in Germany and Scandinavia conceptions of *Bildung* became the general philosophical framework to guide both formal and informal education. *Bildung* concerns the whole range of education from setting educational objectives in general towards its particular operation in different school subjects, among them science education. In more recent years, the concept of *Bildung* has slowly begun to be used in the international science and environmental education literature. This paper presents a systematic analysis of the international literature concerning the use of the concept of *Bildung*, with a view on its meaning in and for science education. At least five versions based on or closely connected to the tradition of *Bildung* can be identified: (a) Von Humboldt's classical *Bildung*, (b) Anglo-American liberal education, (c) Scandinavian folk-*Bildung*, (d) democratic education, and (e) critical-hermeneutic *Bildung*. These different understandings of *Bildung* are discussed in relation to their historical roots, educational theory, critique, and their relation to philosophies of science education, such as different visions of scientific literacy. Based on critical-hermeneutic *Bildung*, the paper theoretically develops views of critical-reflexive *Bildung* as an educational metatheory. It is connected to ideas of transformative learning, sustainability education and a *Vision III* of scientific literacy. Finally, some implications of critical-reflexive *Bildung* for teaching and learning are discussed.

KEYWORDS

Bildung; educational metatheory; philosophy of science education; visions of scientific literacy; socio-scientific issues; emancipation; citizenship education; environmental education; *Didaktik*

Introduction

In Central and Northern Europe (especially in the German-speaking countries and Scandinavia) there is a socio-philosophical and educational tradition called *Bildung*, which has developed since the second half of the eighteenth century (Horlacher, 2016). The educational roots of *Bildung* are generally referred back to the German philosopher, diplomat and politician Wilhelm Von Humboldt (1767–1835) (Nordenbo, 2002; see also Von Humboldt,

2000, written originally in German 1793), who based his writings on notions of the German philosopher Immanuel Kant (1724–1804) and his student Johann Gottfried Herder (1744–1803).

Liedman (2001, p. 351) explains the classical educational understanding of *Bildung* in the following way: ‘The backbone of the concept of *Bildung*, both in Humboldt’s version and later [...] is the notion that knowledge, or at least some knowledge, fundamentally changes and develops a human being’ (our translation). Similarly, Kivelä, Siljander, and Sutinen (2012, p. 304) suggests: ‘*Bildung* in the most general Kantian sense is a person’s becoming a subject, a human being’s attempt to overcome external determination and infancy’ by learning certain knowledge, but also achieving a certain set of skills.

Caused by its complex and multifaceted cultural history there is no precise English translation of the term *Bildung*. Liedman (1997, pp. 230, 231) writes:

With Herder the concept of *Bildung* became popular especially in the area of education, first in the German speaking cultural circuit and shortly thereafter also in the Scandinavian [in Sweden as ‘bildning’; in Denmark and Norway as ‘dannelse’] and Russian [as ‘obrazovanie’] cultural contexts. In England, France and Italy it was never established; still it is not possible to translate ‘*Bildung*’ [...] to English, French or Italian. Words like ‘education’, ‘formation’, ‘culture’ or ‘cultivation’ are usually suggested. But none of them are quite adequate. (our translation)

In July 2016, *Google Translate* suggested for both the German term *Bildung* and the corresponding Swedish term *bildning*, among others, the following translations: ‘education’, ‘formation’, and ‘culture’. The German term was also suggested to be translated with e.g. ‘forming’ and ‘shaping’, and the Swedish term with e.g. ‘learning’ and ‘cultivation’. The translation of *Bildung* as only ‘education’ ignores its distinctive historical and cultural roots and the unique philosophical frameworks behind the concept, which nowadays – as will be discussed further below – also often include critical knowledge, value consciousness, ethics and responsibility.

In many views referring to the classical understanding of *Bildung*, the natural sciences have not been regarded as a knowledge domain contributing to *Bildung*. *Bildung* was – and still sometimes is (e.g. Schwanitz, 1999) – mainly restricted to language education and the fine arts (Horlacher, 2016). However, there were exceptions in history, such as the Swedish botanist and *Bildung*-thinker Carl Adolph Agardh (1785–1859) who already in 1828 asked why certain literary works are more important to be learned than knowledge about the physical world we live in (Liedman, 2001).

During the last decades, some initiatives have been started from Germany, Scandinavia (Sweden, Denmark and Norway) and other countries (e.g. Brazil) to renew the discussion about what implications the concept and tradition of *Bildung* has on science education (e.g. Fischer, 2001; Gustafsson, 2006; Hofstein, Eilks, & Bybee, 2011; Marks & Eilks, 2009; Nilsson, 2010; Paulsen, 2006; Schulz, 2014a; Sjøberg, 1998; Sjöström, 2007, 2013; Zuin, 2012). For example, in 1998 Svein Sjøberg published the first edition of his Norwegian teacher education textbook *Science as part of Bildung for all – a critical subject-Didaktik* (our translation). It was soon translated into both Swedish and Danish and has become a standard text in science teacher education throughout Scandinavia.

In the German speaking countries there has constantly been a debate about what is to be meant by *Bildung* in connection to the teaching and learning of science (Marks, Stuckey, Belova, & Eilks, 2014), although with different degrees of intensity. Unfortunately, this discussion only reached the international science education arena about 20 years ago. A key

publication on overcoming this gap was provided by Westbury, Hopmann, and Riquarts (2000). It included a number of articles by seminal scholars of the German *Bildung* tradition, either translated to English or reviewed by them for an international audience. Among the articles is the work by Von Humboldt from 200 years ago and a chapter by Wagenschein (2000), who discussed how students' *Bildung* in natural sciences can be achieved; the chapter is based on a set of papers published by him in the 1960s.

Since an increasing usage of the concept of *Bildung* in recent years was observed in the international science education literature, it is important to understand how common it actually is and how the concept is used in relation to other philosophies of science education. We were especially interested in how *Bildung* is used in comparison to the broadly used concept of 'scientific literacy'.

Therefore, in this paper we present a systematic analysis of the internationally available literature on the use of the term *Bildung* when it comes to science education. Parts of what is called 'environmental education' is closely related to science education (Dillon, 2014) and therefore it is included as a search term in the analysis made in this paper. In the following, when we use the term science education, we incorporate environmental education. The analysis is based on a structured search in the Web of Science, ERIC and Google Scholar, followed by a characterisation of the uses of the concept in the publications found. Before that, based on literature in general education, different concepts and traditions of *Bildung* are discussed and later connected to the literature in science education. The paper suggests – partly based on the result of the literature analysis and partly on our own thoughts and argumentation – that an advanced understanding of *Bildung* can form a contemporary metatheory for science education in the twenty-first century, with many implications for teaching and learning.

The paper starts with a section where we describe the *Bildung* concept and its history, five different educational traditions based on or related to it, and how and why the concept has been subject to critique. This discussion is followed by a literature analysis on the explicit use of *Bildung* in the international science education literature. In the final sections we first compare different *Bildung*-traditions with different philosophies of (science) education, and then plead for 'critical-reflexive *Bildung*' as a metatheory for contemporary (science) education. Finally, we compare *Bildung* in the science subjects with different visions of scientific literacy and also outline some implications for science teaching and learning.

Conceptualizations and critique of the concept of *Bildung*

History of Bildung

In the beginning, the concept of *Bildung* had theological and spiritual connotations. Meister Eckhart (1260–1328) introduced the term as early as in the late thirteenth century, when he translated the Bible from Latin into German. He used it as a term for transcending 'natural existence and reach real humanity' (Horlacher, 2016, p. 8). Then it took roughly five hundred years until the term started to be used in educational contexts, meaning self-formation. One of the first to use it in this way was Herder, who in 1769 developed his educational concept of *Bildung*. 'He understood *Bildung* as a counter-concept to the rationality of the Enlightenment and emphasised the importance of feelings and sentiments in educational settings' (Horlacher, 2016, p. 11).

The rooting of *Bildung* in Romanticism was later intertwined with contemporary ideas of Enlightenment (Reichenbach, 2014). Based on the works of Von Humboldt (see Von Humboldt, 2000; written originally in German 1793), it became a 'modern' ideal for education in the late eighteenth century (e.g. Kivelä et al., 2012; Masschelein & Ricken, 2003; Nordenbo, 2002). *Bildung* became also connected to morality and virtue, or in one word to humanity (Reichenbach, 2016).

In the nineteenth century *Bildung* became mainly understood as a value and commodity (Reichenbach, 2016). Self-realisation was emphasised in favour of usefulness and classical-philological disciplines in favour of the natural sciences (Horlacher, 2016). In the late nineteenth century there were many critical voices concerning *Bildung*. For example the German philosopher Friedrich Nietzsche (1844–1900) was critical to the misuse of *Bildung* and that it essentially had become a commodity (Thompson, 2005).

During the first half of the twentieth century German educational scholars used the concept 'to indicate an anti-materialist orientation and an inward ennoblement of the soul' (Horlacher, 2016, p. 5). After the Second World War this view was challenged by e.g. the ideas of *Critical Theory* and its redefinition of *Bildung* as emancipation. Critical Theory suggested emphasising the political dimension of the concept of *Bildung*. Two important scholars of critical theory were Max Horkheimer (1895–1973) and Theodor Adorno (1903–1969) (see further below).

During the last decades, which more generally can be characterised by a policy discourse focusing on standards, competencies and benchmarks, the concept of *Bildung* has experienced a revival as a counter-concept. Horlacher (2016, p. 118) suggests: '*Bildung* is [...] seen as a tool to promote political education, and foster public spirit and identity in [...] multicultural [...] societies'. Recently, Rucker and Gerónimo (2017) theoretically connected *Bildung* to the concept of complexity and some scholars have even started to discuss it from post-modern and posthuman perspectives, where both relations and responsibility are emphasised (e.g. Taylor, 2017) (see further below).

Contemporary conceptualizations of Bildung

Schneider (2012) describes a contemporary understanding of *Bildung* as a reflexive event and its function to design and form the self, a complex meaning-making process that occurs from childhood to advanced age. It can be understood as a lifelong challenge and opportunity (Biesta, 2002a) and is suggested to be 'the process of developing critical consciousness and of character-formation, self-discovery, knowledge in the form of contemplation or insight, an engagement with questions of truth, value and meaning' (Vásquez-Levy, 2002, pp. 118, 119).

In the works of the German scholar and educational philosopher Wolfgang Klafki (1927–2016) the terms self-determination, freedom, emancipation, autonomy, responsibility, reason, and independence are suggested to be crucial notions in relation to contemporary understandings of *Bildung* (Klafki, 2000). Similarly, Willbergh (2015) claims that the idea of autonomy is essential for *Bildung*. However, the concept should not only be understood individualistically; it is also characterised by humanity and morality (Fischler, 2015). It is about the individual being embedded in the world (Løvlie & Standish, 2002) or as Nordenbo (2002) writes: '*Bildung* is about the individual in society' (p. 346).

Bildung – in a contemporary meaning of the concept – has both an educational dimension and a political; it is about both autonomy and responsible citizenship. According to Nordenbo (2002), even for Von Humboldt, *Bildung* was never a private matter. He suggested that *Bildung* understands personal morality and politics as two sides of the same coin. *Bildung* consists of autonomous self-formation and reflective and responsible action in, and in interaction with, society (see also e.g. Fellenz, 2016). This tension between personal and societal values manifests itself also in other areas of research, such as, e.g. *Character and Citizenship Education* (Sim & Ling Low, 2012; Staeheli & Hammett, 2010) and *Environmental and Sustainability Education* (Van Poeck & Vandenabeele, 2012).

Due to its both educational and political dimensions, *Bildung* makes us think differently about education (Biesta, 2002a). The concept can be used both in an apolitical sense, in the meaning of reflective distance from society, and as a ‘political fighting word’, in the meaning of agency (Horlacher, 2012). Biesta (2012a) characterises *Bildung* as a (neo)humanist tradition and argues (in contrast to many other *Bildung*-scholars) that it differs from the Greek tradition of ‘paideia’. The latter is, he claims, connected to cultivation, socialisation and empowerment, whereas *Bildung* is connected also to the idea of emancipation, which adds an explicit political dimension to it (see further below).

Probably, John Dewey (1859–1952), in his famous book *Democracy and education: an introduction to the philosophy of education* from 1916, used ‘education’ with this meaning (Retter, 2012). Similarly, Nohl (2009, p. 287) writes: ‘Education is not only concerned with learning facts, acquiring skills and becoming socialized in roles; education should also help us to challenge and subsequently change our yet unchallenged psychological and cultural assumptions that constitute our “meaning perspectives”’. Such changes of our meaning perspectives are the goal of what recently has been called ‘transformative learning’ (Nohl, 2009; Sterling, 2011; Thomas, 2009). According to Bohlin (2008, p. 8), transformative learning theory, although only seldomly explicitly associated with the idea of *Bildung*, ‘indicates ways to implement the ideal of moral *Bildung* in educational practice’ (see also Bohlin, 2013).

Five different versions of *Bildung*

Gustavsson (2012, 2014) has – mainly from a Swedish perspective – identified three traditions related to *Bildung*, which are well-established today and all of them have developed over time. We call them (a) classical *Bildung*, (b) liberal education, and (e) critical-hermeneutic *Bildung*. In addition to these three versions Burman (2011) identified two further civic-oriented *Bildung*-related traditions: (c) the Scandinavian *folk-Bildung* tradition, and (d) democratic education. Furthermore, other versions of *Bildung* have been or are still present (see e.g. Horlacher, 2016), but in our view the five versions identified by Gustavsson and Burman illustrate the richness of *Bildung* cultures appropriately and will therefore be described in more detail below:

(a) *Classical Bildung* is based on the German philosopher and educational politician Von Humboldt (2000). Von Humboldt understood *Bildung* as ‘a process of individualization where humans develop their personality through studies and reflections in a diverse, harmonious and unique way, and thus become a human original rather than a copy of others’ (Burman, 2014, p. 127; our translation). However, today Von Humboldt is often – at least in universities – more associated with the free search for knowledge, free from influences both from the state and the market. Von Humboldt’s emphases are also sometimes misused. His idea that

Bildung manifests itself mainly in language led to a long time of devaluing the natural sciences as being part of *Bildung*. This led to a long time of over-emphasising the humanities to constitute classical *Bildung* against the science subjects.

(b) *Liberal education*, which is an Anglo-American version of *Bildung*, can be tracked back to Von Humboldt (Løvlie & Standish, 2002), although the two traditions are largely independent today. According to Reichenbach (2014, p. 66), a core difference between German *Bildung* and liberal education is the 'crucial role of Romanticism in the German discourse on *Bildung*'. Just like *Bildung*, liberal education is a rich and complex concept and its purpose can be described as the development of human beings who know how to use their minds and know to think for themselves (Hadzigeorgiou, 2015). The character formation ideal is sometimes emphasised, sometimes instead a classical canon of topics (Burman, 2014). Humanism and generalisation are central – in contrast to specialisation – and also that education must be free from short-term instrumental thinking. In a report about liberal education for the twenty-first century one can read:

the term 'liberal education' is [...] used [...] as a description of the kinds of learning needed to sustain a free society and to enable the full development of human talent [...] and it is] essential for success in a global economy and for informed citizenship. (AACU, 2007, p. 18)

The thought of lifelong learning, which for example is important in contemporary European policy debate, is related to this type of thinking. In America, during the last decades, there has been a tension between traditionalists (emphasising the traditional canon) and those emphasising more critical perspectives (Burman, 2014).

(c) The *Scandinavian folk-Bildung tradition* ('folkbildning' in Swedish) is a unique tradition from the late nineteenth century in Scandinavia. It might be translated as '*Bildung* for the whole people' and is a tradition that is less academically oriented than the classical German *Bildung* tradition. The German basic notion was combined with a pronounced benefit-approach. *Bildung* should be useful for the creation of a society with justice. An important goal for many of its proponents was to empower members of the working class. In 'folkbildning', the political dimension was much more explicit than in the classical German version, but it was not radical. The famous Swedish pedagogue Ellen Key (1849–1926) emphasised *Bildung* as a relevant concept both on individual and societal levels. Children should be educated to be civic citizens. School should encourage students to become free, responsible citizens, with a developed individuality – cognitively, morally, as well as aesthetically (Burman, 2014).

(d) *Democratic education* is the idea of a school for all, which was developed in the USA by mainly Dewey. In his book *Democracy and education* he argued that school has a crucial role to play in every democratic society. He suggested that the basic mission of school is to prepare for citizenship. This requires that students can develop quite freely (Burman, 2014). According to Väkevä (2012, p. 277), Dewey's most important contribution to the *Bildung* tradition was his 'analysis of the social-ethical underpinnings of a society that fosters democratic habits'. Dewey used the term *Bildung* in his work, although not systematically (Bauer, 2003). Philosophically, democratic education is connected to pragmatism, and also to its successor progressivism (see further below). However, just like the concept of *Bildung*, pragmatism is a complex concept, which can be understood in several different ways (Kivelä et al., 2012). It is interesting that Kivelä et al. (2012, p. 304) conclude that on a general level there is no significant difference between 'growth-theoretical *Bildung* ideas and the ideas of pragmatists such as Dewey, James, and Mead'.

(e) *Critical-hermeneutic Bildung* is based on the work by Hans-Georg Gadamer (1900–2002) and Paul Ricoeur (1913–2005) and can be described as ‘*Bildung* as a journey’ (Gustavsson, 2012, 2014). Especially during the 1950s and 1960s, and in interaction with the work of Gadamer and Ricoeur, the German educational philosopher Erich Weniger (1894–1961) developed an understanding of *Bildung* connected to educational practice. It was further developed by Klafki based on critical theory and his approach is still important in education in the German speaking world and some parts of Scandinavia. Klafki used the term *Allgemeinbildung*. Within this concept, part of the word, *Allgemein* (which can be translated as ‘general’), has two dimensions. The first dimension means to achieve *Bildung* for all persons (like in the Swedish approach of ‘*folkbildning*’). The second dimension aims at *Bildung* in all human capacities (e.g. Klafki, 2000). Klafki’s thinking is based on the thought that responsible citizens in a democratic society need *Bildung*. Based on Klafki’s educational philosophy, the Danish philosopher Kemp (2005) has written about an educational metatheory for forming citizens of the world. According to him *Bildung* has a moral purpose, while education aims mainly at skills. He suggests that the world citizen should contribute the joint responsibility of the Earth and also should be able to overcome the contradiction between the individual and the state.

Critiques on the concept of Bildung and first ideas of a latemodern reformulation

In educational policy, much that was done in the name of *Bildung* was more about socialisation than about emancipation and subjectification (Biesta, 2012a). Reichenbach (2014) describes how the use of the term underwent periods of trivialization, especially during the 1960s and 1970s, when the concept largely disappeared from the educational policy agenda, at least in some countries (Biesta, 2002b; Liedman, 2001). The discourse of education underwent an empirical turn and focus shifted to psychology, sociology, and assessment, instead of discussing educational values, ethics and policies, although integrating *Bildung* with critical theory by Weniger and Klafki was an important exception (Biesta, 2002b; Horlacher, 2016). Since the early 1980s there has been a renewed interest in *Bildung* in many countries, although the question of *Bildung* is quite often still approached in a rather instrumentalist manner in the policy debate (Biesta, 2002b).

Schaffar and Uljens (2015) have identified the following two central points of criticism related to *Bildung*: (a) a logico-conceptual type of critique, where *Bildung* has been called a container word and the meaning of emancipation has been questioned, and (b) a socio-cultural critique, where *Bildung* only is reachable for the elite and that it is thus solidifying the existing cultural power structures.

During the last decades, *Bildung* has been also problematized from late- and postmodernist points of view. Masschelein and Ricken (2003) went so far that they suggested abandoning the concept. In opposite, Biesta (2002b), among others, has claimed that *Bildung* still can work as a critical concept for education in a postmodern world (see further below). For him, ‘the role of the individual in the process of *Bildung*, [...] has to be understood as a *reflexive* process’, i.e. a process where the individual establishes both a relationship and a critical stance towards the existing culture and society (Biesta, 2012a, p. 817). In this process of ‘subjectification’ the individuals become autonomous subjects of action and responsibility (Biesta, 2012b). This orientation ‘tries to capture a conception of human subjectivity that is not selfish or self-centered, but always understood as being in responsible relation with

other human beings and, by extension, with the natural world more generally' (Biesta, 2013, p. 739). Biesta (2012b) describes this as highly political and intervening in and reconfiguring of the existing order of things.

Zembylas (2006) discussed emancipation in science education based on Roy Bhaskar's philosophy of meta-reality and claimed that it offers an interesting alternative to modernist and postmodernist accounts. Similarly, our position can be described as a reflexive (late) modernity (a term borrowed from Beck, 1992). Critical-reflexive *Bildung*, which will be described further below, is based on a theoretical stance that is inspired by philosophical, social and educational ideas such as emancipation and critical theory, but also postmodern problematization.

Coming from the history and theory of the concept of *Bildung* in the literature in education, the following section tries to identify where and how *Bildung* appears in the international science education literature. For this purpose, a systematic analysis of international databases on educational literature was performed. The findings were analysed on how *Bildung* is currently used in the debate on science education.

Use of *Bildung* in the international science education literature

Method

In this section we provide a thorough analysis of the most common databases operated in the scholarly field of education, namely the Web of Knowledge, ERIC, and Google Scholar. In these databases the term 'Bildung' was searched in autumn 2016 in connection to 'science education' and biology, chemistry, physics and environmental education, respectively. Analysis of the found papers focused on how the term *Bildung* is used in connection to science education. All references found in the Web of Knowledge and ERIC as well as the most prominent hits in Google Scholar in terms of ranking in the Google list and quality of the publication type (peer-reviewed international journals, books and edited book chapters) were analysed until a saturation of the data in terms of aspects related to the use of the term of *Bildung* was observed.

Findings

A first search for the combination of the terms 'Bildung' and the unspecified term 'science education' led to 6200 results in Google Scholar and to 35 and 8 results in Web of Knowledge, and ERIC, respectively. A more refined search using the keywords 'biology education', 'chemistry education', 'physics education' and 'environmental education', respectively, in combination with 'Bildung' resulted in between 240 and 2060 hits in Google Scholar and only very few hits in the other databases (see Table 1).

As a first step of the analysis, the numerous results from the Google Scholar search using the term 'science education' were processed. The first 250 publications were analysed to whether the paper was written in English language, whether the term *Bildung* was used in the text or only in the list of references, and whether the paper dealt with relevant content at all. After approximately 200 hits no more relevant results were found, with most of the results being either references or papers written in German. In this step all publications published in German language were excluded (approximately 60 results). Most of these

Table 1. Hits for ‘Bildung’ searched in connection to ‘science education’ and biology, chemistry and physics education as well as ‘environmental education’, respectively.

<i>Bildung</i> connected to	Web of knowledge	ERIC	Google scholar
Science education	35	8	6200
Biology education	3	0	240
Chemistry education	4	1	397
Physics education	1	0	557
Environmental education	3	8	2060

papers had an English abstract and/or English keywords and therefore appeared in the search results. About 20 papers written in German had a totally non-educational focus and only emerged because the word *Bildung* in German also means ‘emergence’ or ‘formation’, e.g. the emergence of a fallout during a chemical reaction.

During this step of analysing the English language results, it became obvious that most of them (58 results) were from science education, but only included the word *Bildung* in the list of references. Another cluster of papers (46 results) consisted of literature that actually dealt with the issue of *Bildung*, but stemmed from domains other than science education, mostly early childhood education or political education. From the remaining results, only publications from peer-reviewed journals, books, and chapters in edited books were analysed. In total, 27 peer-reviewed science education papers, books and book chapters used the term ‘Bildung’ explicitly for argumentation or illustrational purposes.

Next, the results for the selected sample of 27 publications were compared with the findings of the other platform searches. All papers from the Web of Knowledge and ERIC that fulfilled the same criteria, as operated in the selection process described above, were also found in the selected Google Scholar findings list. An analysis of each of the first 150 first hits with biology, chemistry, physics and environmental education, with the same criteria, led to only three more results relevant to this analysis. All of them stemmed from the search for environmental education. In a last step, the hits 250–350 from Google Scholar using the term ‘science education’ were checked for any new relevant aspect, but none was found. Together with the comparison to the other databases, the list of the 30 identified references (starred in the reference list) can be interpreted as being saturated. The obtained literature was then systematically reviewed and categorised according to the way the concept of *Bildung* is utilised.

Discussion

The papers that constitute the first and most important category in using the term *Bildung* either make *Bildung* the main subject of discussion or at least extensively use the concept as a major starting point for discussion and the theoretical framework. This category mainly consists of the works constituting the German and Scandinavian-based initiatives for a stronger recognition of the *Bildung* concept in the field of science education (Hansen & Olson, 1996; Hofstein et al., 2011; Sjøberg, 1997, 2002; Sjöström, 2013; Sjöström, Eilks, & Zuin, 2016). It also encompasses a paper on the issue of relevance of science education by Stuckey, Hofstein, Mamlok-Naaman, and Eilks (2013). This paper uses the concept of *Allgemeinbildung* to localise the dimensions of relevance, which they generally define as time and goal. Referring back to Klafki and his concept of *Didactical Analysis*, Stuckey et al. point out that a topic that contributes to *Allgemeinbildung* (and therefore is relevant) should enable the

students to both be aware of his or her own needs in society as well as be prepared to make decisions that positively affect the society as a whole. Another key publication in this category is the edited book by Westbury et al. (2000), which can, as already mentioned above, be regarded as a thorough introduction of *Bildung* to the international science education community. This book as well as the works based on it also use the *Bildung* concept in accordance with Klafki and different developments of his thoughts.

In the remaining publications *Bildung* does not play such a dominant role, but nevertheless it can be characterised either as an important aspect of the underlying theoretical concept, a starting point for discussion or an argumentational pattern. Several times *Bildung* is mentioned in the context of two divergent educational traditions, which Fensham (2009) labelled as the 'Anglo-American' and 'Germanic' traditions, respectively (p. 1081). He points out that in the Anglo-American tradition teachers are 'agents of the system' (p. 1082) due to the fact that the content they are supposed to teach as well as the assessment of learning progress is strongly regulated by (curriculum) authorities. Thus, the teachers' professional freedom is limited to the pedagogy of teaching and learning. This issue is also mentioned with reference to *Bildung* in Fensham's book *Defining an identity* (2004). Opposite to that, Fensham (2009) describes that the German term *Bildung* (and therefore also *Didaktik*, in the German and Scandinavian meaning of the term; see e.g. Fischler, 2011) provides a much larger extent of responsibility for the teachers: they are supposed to transform 'knowledge sources' (p. 1082) into meaningful content. In this context, he also refers to the Didactical Analysis by Klafki and emphasises the fact that only two out of five questions, namely the methodological ones, are part of science teacher education programmes in English-speaking countries. By doing so, he aims at initiating a discussion about the role of authority and policy in these two traditions.

Westbury (2000), who also extensively addresses the issue of contrasting traditions in the book mentioned above, states that German teachers 'are guaranteed professional autonomy, "freedom to teach", without control by a curriculum in the American sense' (p. 17), although even they have to follow governmental syllabi and standards. In this context DeBoer (2011) emphasised that a deep confidence in the teachers' competence to 'interpret the norms, values and traditions of the society and transmit them in a way that will transform the character of the youth' (p. 575) is deeply rooted in the *Bildung* tradition. He highlights the strong impact the tradition has especially in Scandinavian countries. For instance, despite the fact that the PISA results were dissatisfactory, Denmark decided not to 'implement a programme of highly specified standards' (p. 576), but to rely on the 'development of individual students' productive participation in society' (p. 576). Bevilacqua and Giannetto (1996) even claimed, with relation to science education, namely the teaching of the history of science, that the *Bildung* idea implies 'proper [...] educational motivations' (p. 241).

A multi-perspective comparative analysis of the two approaches can be found in the book *Didaktik and/or curriculum. An international dialogue* by Gundem and Hopmann (2002), but not all publications highlight solely the incompatibilities of the two traditions (namely the Anglo-American and German-Scandinavian). Van Dijk and Kattmann (2007) described the potential of 'cooperation and comparison' between them 'within educational research' (p. 887) by pointing out particularly strong parallels between *Fachdidaktik* (the German term for domain-specific educational research and knowledge) and the concept of PCK. Based on the merge of these two concepts (and also taking into account Klafki's Didactical Analysis) they designed the 'educational reconstruction for teacher education (ERTE)' model for the

study of teachers' PCK (see also Duit, 2007). Generally, all of the publications focusing on a comparison and/or juxtaposition of these two traditions highlight the strong and deeply rooted impact of cultural (and thus political) as well as historical aspects, or, as Fensham (2009) puts it: 'In every country, the teaching of science (and indeed the whole of schooling) takes place in ways that have a long and firmly established cultural history' (p. 1088). This has to be taken into account when conducting research, interpreting results or comparing different educational systems to each other.

Moving away from the teachers' perspective, the *Bildung* concept is also used to justify the selection of educational content or to critically analyse the curriculum in science education. Fensham (2000) characterised *Bildung* (again with recourse to Klafki) as a useful set of criteria determining which content should be taught in science classrooms and which aspect of this content should be particularly highlighted. Just as in his other works on this matter cited above, he raises the question whether the term *Bildung* has been substantially acknowledged and understood in the Anglo-American educational community. In his paper on enhancing the relevance of science education, Bolte (2008) followed a similar path stressing that *Bildung* is the theoretical underpinning for the selection of relevant topics that enable the students to find orientation in society. Witz and Lee (2009), who primarily addressed the teachers' perspective by analysing reasons for opposing or supporting the implementation of socio-scientific issues (SSIs), draw attention to the fact that beyond the mere scientific content there is always a forming element (*Bildungsgehalt*) for the personality of the learner, which is taken into consideration by *Bildung* theory. This element enables the student to actively engage with the subject matter.

The term *Bildung* also appears in the context of tertiary education, but only once in this analysis. Krageskov Eriksen (2002) applied the concept of *Bildung* to tertiary chemical education in a very detailed way arguing that chemists need ongoing reflectivity to act as social actors also outside a narrow academic context. *Bildung* is not, in this way, limited to education, but related more generally to good scientific and chemical practice.

Overall, all papers describe *Bildung* as a positive and fruitful concept that aims at the formation of the learner as a person and contributes to the development of his/her full potential. In this context, as already indicated above, *Bildung* is sometimes contrasted with the output-oriented approach that became prevalent after the results of large-scale studies such as PISA. Neumann, Fischer, and Kauertz (2010) outlined the debate that emerged in Germany (where the *Bildung*-approach is obviously rooted especially deeply) after the deficits in achievement that was revealed by the first round of PISA; they argued that there had been a paradigm shift from a *Bildung*-perspective towards a 'scientific literacy'-perspective. However, Fischler (2011) criticised that this has led to a 'marginalization of content' (p. 31). The issues of selecting suitable subject matter and finding appropriate ways to introduce it to students are either neglected or entrusted to a few external authorities.

Talking about environmental education, health education as well as Education on Sustainable Development (ESD), Schnack (2008) highlights the relevance of *Bildung* for these fields, aiming to 'prevent [them] from being reduced to instruments of ideology or policy' (p. 181). Focusing on these three fields, he argued that education must not only be characterised by the outcomes but also by a reflection of the 'broader educational value' (p. 184) of the contents. *Bildung*, he emphasised, should not be reduced to questions of effectiveness, a claim that can be connected to the debate around the two contrasting educational traditions described above. In a later publication, Mogensen and Schnack (2010) built on these

ideas by suggesting an approach to ESD, which is based on action competence and *Bildung*. Læssøe (2010), similarly, criticised 'the widespread normative and instrumental orientation among environmental education practitioners' (p. 39) and contrasted it with a *Bildung*-oriented approach. Also Aikenhead (2006) subsumes the term 'Bildung' under the general idea of 'humanistic school science worldwide' (p. 21), together with such concepts as science, technology, society and environment (STSE), science for public understanding, science-technology-citizenship, citizen science, functional scientific literacy, PUS, SSI, or cross-curricular school science. In general, *Bildung*-oriented science education is an example of humanised science education (Schulz, 2009).

Overall, we can conclude that there has been a growing mentioning and usage of *Bildung* in the international science education literature in recent years (e.g. Elmoose & Roth, 2005; Fensham, 2004; Fischler, 2015; Hofstein et al., 2011; Schulz, 2014b; Sjöström, 2013; Sjöström & Eilks, *in press*; Ståhl & Hussénus, 2017; Stuckey et al., 2013; Zuin, 2012). All the analysed publications clearly state that *Bildung* in relation to science education is connected to, but not identical to, 'scientific literacy'. Although some newer versions of scientific literacy encompass e.g. science for critical citizenship (e.g. Albe, 2015), complex versions of SSI-based science education (e.g. Zeidler, 2015), and STSE education (e.g. Pedretti & Nazir, 2015), the earlier discussion in this paper shows that such interpretations might not come up with the unique cultural history of *Bildung* as well as the broadness and holistic nature of the concept. Many publications emphasise that *Bildung* is a broader concept on its own right and should become better recognised in the international debate about the future of science and environmental education.

***Bildung* and its relationship to general philosophies of (science) education**

Essentialism, progressivism, and reconstructionism are three major contemporary educational philosophies. Essentialism focuses on disciplinary knowledge, progressivism on the formation of the student, and reconstructionism on transformation of society through critical citizenship. Another organiser for philosophies of education was suggested by Blades (2008) with reference to science education. He described – based on five books published 1990–2002 – three philosophical traditions in science education since the 1970s (after the rationalist-objectivist focus during the 1960s): (a) science education for enlightenment (e.g. Matthews, 1994, 2000), (b) science education for citizenship (e.g. Hodson, 1998), and (c) science education for reconstruction (e.g. Weaver, Morris, & Appelbaum, 2001).

We would claim that in the practice of science teaching the rationalist-objectivist focus is still often present (a predominantly transmissive view focused on content learning and the structure of the discipline), but a sustainable development view and perspectives of ecological modernisation have become more common during the last three decades (Huckle & Wals, 2015; Kopnina, 2014). Such a view is oriented towards society, but often lacks perspectives from the research fields of *Science and Technology Studies* (e.g. philosophical, historical, and sociological perspectives) and *Environmental and Sustainability Education* (e.g. socio-critical perspectives) (Sjöström, 2013; Zuin & Pacca, 2013).

With reference to the *Bildung* concept, Nordenbo (2002) rejects both educational utilitarianism and progressivism as one-sided positions. Similarly, Thompson (2005) claimed that pragmatism (which is philosophically related to progressivism) has always mistrusted autonomous subjectivity and essentialisms, which is not the case for *Bildung*.

The above mentioned contemporary educational philosophies can be connected to different *Bildung*-traditions in the following ways:

- Classical *Bildung* (a) can be connected to essentialism (focusing mainly on disciplinary knowledge), especially when *Bildung* is connected to free basic research, which is supposed to – in a linear way – lead to technological development and utility.
- Progressivism (focusing on the formation of the student) can be connected to civic-*Bildung* (c and d), i.e. both the Scandinavian ‘folk-*Bildung*’-tradition (c) and democratic education (pragmatism) (d). It has also connections to modern forms of ‘liberal education’ (b).
- Reconstructionism (focusing on the transformation of society) can be best connected to critical-reflexive *Bildung* (see further below).

Using another organiser, Simonneaux and Simonneaux (2012) described what they call different ‘educational configurations’ within science education (especially for environmental SSIs). An educational configuration consists of teachers’ epistemological postures (scientism, utilitarianism, scepticism, or relativism), various didactical strategies (doctrinal, problematizing, critical, or pragmatic), and various conceptions of knowledge (universal, plural, engaged, or contextualised). Particularly they described four combinations of these, which they called *archetypical educational configurations*. These are:

- Hierarchical configuration (scientism; doctrinal; universal knowledge).
- Professional configuration (utilitarianism; pragmatic; contextualised knowledge).
- Problematizing configuration (scepticism; problematizing; plural knowledge).
- Critical configuration (scepticism; critical; engaged knowledge).

Compared to the four archetypical educational configurations and based on how the concept of *Bildung* is used in the science education literature, we would claim that the concept is mainly connected to the latter two configurations (problematizing and critical). Nowadays the concept of *Bildung*, in addition to connotations related to its historical roots in both Romanticism and Enlightenment, stands for critical-democratic awareness and agency.

However, Hadzigeorgiou (2015) has problematized the idea of ‘Science Education As Socio-Political Action’ (SEASPA). He regards SEASPA as ‘based upon a progressivist/reconstructionist educational philosophy, which gives primacy upon the social context of science and science education’ (p. 261). He claims that SEASPA in the versions by e.g. Roth and Calabrese Barton (2004) ‘downplays the importance of content knowledge’, whereas the SSI approach by e.g. Zeidler ‘stresses the centrality of science content knowledge and also knowledge of NOS’ (p. 261). Hadzigeorgiou emphasises its opportunities, for example ‘to empower students as citizens’ and ‘moving away from an absolute view of knowledge’ (p. 260), but also criticises it from the perspective of liberal education. He writes: ‘The central idea behind the critique is that a conception of science education as sociopolitical action downplays the importance of knowledge for its own sake and totally neglects personal/aesthetic dimensions of science’ (p. 259). Elements such as wonder, awe, mystery and pleasure should not be forgotten in science education.

Similarly, Donnelly (2004) problematized the ongoing humanisation of science education and Stuckey et al. (2013) pointed out that there are also other aspects of science education than learning for societal participation that make science education relevant both to the

individual and to society, e.g. career orientation, qualification, and recruitment of scientists and engineers. According to Donnelly (2004), a too humanistic science education 'risks losing sight of the distinctive quality of natural science' (p. 780) and in line with this Sjöström (2013), in his paper about *Bildung*-oriented chemistry education, emphasised not only socio-political awareness and action, but also a more general philosophical awareness (see also Sjöström & Talanquer, 2014).

Schulz (2014a, 2014b) has argued for the importance of explicitly articulated philosophies/metatheories of science education. As we have claimed above different versions of *Bildung* have connections to all the above mentioned contemporary educational philosophies (essentialism, progressivism, and reconstructionism). There are also connections to all the four archetypical educational configurations (hierarchical, professional, problematizing, and critical). Furthermore, there are connections to liberal education (described as *Bildung*-tradition b), as well as to socio-political action. However, in the rest of the paper we will especially focus on a version of *Bildung* which we call critical-reflexive *Bildung*. Critical-reflexive *Bildung* – as the literature review indicates – clearly reflects how the concept of *Bildung* nowadays mostly is used in the international science education literature.

Critical-reflexive *Bildung* as a metatheory for contemporary (science) education

Criticism on the concept of *Bildung* can be counteracted by arguing for a more complex version of it and by emphasising that *Bildung* is something for everyone in the late/post-modern global society (Sjöström, 2013). It should also be compatible with contemporary concepts of emancipation (e.g. Säfsström, 2011). We suggest to call such an approach critical-reflexive *Bildung*, which we regard as a further developed version of critical-hermeneutic *Bildung* and Klafki's *Allgemeinbildung* (Sjöström & Eilks, *in press*). It is more influenced by late/postmodern perspectives in contrast to most other *Bildung*-traditions, which are mainly based on Western modernism (Sjöström, *in press*).

Several scholars have tried to reformulate *Bildung* in the context of postmodernity (e.g. Biesta, 2002b; Gur-ze'ev, 2002; Peukert, 2002; Reichenbach, 2002; Wimmer, 2003). Løvlie and Standish (2002, p. 335) summarised the ambition: 'whatever *Bildung* is today, it cannot pretend to have universal validity'. Also Reichenbach (2002) and Peukert (2002) suggest that any certainty about the proper aims of *Bildung* and education has vanished, but that *Bildung* should be about e.g. cultural respect and socio-political justice relevant to all citizens. Similarly, Thompson (2005) has shed light on the ethical relevance of a non-transparent subject of *Bildung* by referring to Nietzsche's and Adorno's criticism of *Bildung*. According to her, 'Adorno is in search of a kind of experience [...] that can be contrasted with that of the knowing subject of the modern tradition' (p. 526). *Bildung*, in this perspective, will bring uncertainty into our relationship to ourselves and to the world around us, which of course has educational implications, not at least for science and technology education in its relevance to understand and react to environmental and sustainability issues. Similarly, Rucker and Gerónimo (2017) recently showed how the concept of *Bildung* is related to the concepts of uncertainty and complexity.

Biesta (2002b) argues against certain modern versions of critical theory-based *Bildung* and critical pedagogy with the ambition to 'read power' from the outside. Instead, he refers

to Latour's networks in which knowledge and power are not separable. For Latour (2004), it is not possible to stay outside a field of competing networks for giving an objective description of the state of affairs. He introduced the concept *matters of concern* to refer to the highly complex, uncertain, and risky state of affairs in which human and non-human entities are intimately entangled. According to Van Poeck, Goeminne, and Vandenabeele (2016) matters of concern allow us to re-think educational practices concerning the dichotomy between objectivism that is underpinning instrumental education and subjectivism that often goes with a pluralistic approach. The implications of Latour's work come close to the message by Foucault that we are always operating in a network of power and knowledge constellations (Biesta, 2002b).

Gur-ze'ev (2002) discussed *Bildung* with respect to critical theory in the perspective of postmodernity. He claimed that 'Horkheimer's position has some similarities with that of present postmodernists in his understanding that belief in a better, positive alternative is a dangerous, naïve optimism that enables one to avoid taking a real critical stance' (p. 402). The late stage of critical theory anticipated some of the postmodern critique of the Enlightenment, but it did not totally abandon the tradition of Enlightenment or commitments of realising *Bildung*. Gur-ze'ev (2002, p. 404) further wrote: 'As counter-education, today's *Bildung* can contribute greatly to the reconstruction of [...] subjectification'.

Based on Gur-ze'ev (2002) and in the light of the postmodern critique of *Bildung*, Taylor (2017) recently asked if a posthumanist *Bildung* is possible. She seems to think so and writes:

A posthuman *Bildung* is a lifelong task of realizing one's responsibility within an ecology of world relations, it occurs outside as well as inside formal education, in virtual as well as 'real' places. [...] It is a matter of spirituality and materiality which means that it is not an 'inner process' but an educative practice oriented to making a material difference in the world. [...] It is education as an ethico-onto-epistemological quest for (better ways of) knowing-in-becoming. (Taylor, 2017, pp. 432, 433)

In this context, *Bildung* can be identified as a crucial experience to the development of individual and collective identities. However, for this continuity and temporality axes take an important role. Continuity refers to the need for cultural content to remain present, even if modified, in the memory. Following this line, it becomes decisive for the development of the capacity of the individual to establish even more complex relationships between the contents of the most varied subjects of knowledge. The information received must be related to each other so that the concepts themselves can be generated, and not just juxtaposed without the reflection that allows the connections between the information to be transformed into conceptual relations. The other determining characteristic is related to the need to consider the temporal links between symbolic products and their respective assimilations. It is of fundamental importance to take into account the historicity immanently present in all cultural products, including science content (Zuin, 2012).

As mentioned above, one especially important component of critical theory is *emancipation*, which over the years has played an important role in many contributions about *Bildung*, e.g. in the works of Klafki (2000). Emancipation can be defined as eliminating oppression and creating conditions for effective agency (Zembylas, 2006). Biesta (2012b) has discussed, based on writings by Foucault, Freire and Rancière, a dialogical approach to emancipation. In such an approach pluralisation of truth and transgression, i.e. doing things differently to show alternatives, are emphasised (Biesta, 2002b).

According to Zuin (2012), *Bildung* implies a transformation of the subject. This demands time for reflection and continuity, in contrast to immediacy and fragmentation of objectified formal rationality, especially for teaching and learning of science and technology currently. This is in line with the concept of critical-reflexive *Bildung*. Concerning the typologies described above critical-reflexive *Bildung* can mainly be characterised with reconstructionism, problematizing and critical configurations (scepticism and plural and engaged knowledge), and socio-political orientation. Furthermore, subjectification is emphasised in addition to socialisation. In relationship to SEASPA we claim that it can function as a bridge between traditional liberal education and activism-oriented education. Critical-reflexivity should be oriented the whole way (and back) from content to processes to applications. It does not exclude a fascination for nature, but involves also a political orientation and a perspective on socio-ecojjustice. In contributions to science education, Elmore and Roth (2005) and Hofstein et al. (2011) described, with reference to Klafki, *Bildung* as involving competences for self-determination, constructive participation in society, and solidarity towards persons limited in the competence of self-determination and participation.

As described above, *Bildung* – in a contemporary understanding of the concept – is a critical concept. We think it can be understood based on the following three criticalities, as suggested by Ebenezer (2013): critical consciousness, critical literacy, and critical agency, or in one word *critical praxis*, where praxis means reflection in practice. With reference to Freire, Galloway (2012, p. 166) writes: 'Praxis must involve both action and reflection; it is a dialectical relation where action should lead to critical reflection and where this reflection, if "true," will lead to action.' If this is connected to critical literacy, it can be defined broadly and regarded as synonymous with critical praxis. It includes then also critical consciousness and critical agency. Accordingly, Lewinson, Flint, and Van Sluys (2002) suggested a broad definition of *critical literacy*, when they described it with the following four dimensions: (1) disruption of the commonplace, (2) interrogation of multiple viewpoints, (3) focus on socio-political issues, and (4) action and promoting social justice. They emphasised that it is not possible to take any informed action against oppression or to promote social justice without expanded understandings and perspectives.

Which consequences does such a vision of critical literacy for all have on science education? Ruitenberg (2009) suggests that any education is politicized, it is never neutral, because any neutrality supports the dominant ideology. As an educator one has to be aware of underlying worldviews, values and ideologies (Jickling & Wals, 2008). Critical citizenship education is in contrast to deliberative approaches of many scholars in the area of education for global citizenship. According to Mannion, Biesta, Priestley, and Ross (2011) the latter is based on three educational traditions: environmental education, development education, and citizenship education. For each of these traditions there are 'critical sub-traditions' (see also Johnson & Morris, 2010). Critical citizenship is characterised by political emotions (e.g. 'the ability to feel anger on behalf of injustices committed against those in less powerful social positions'), understanding of power differences, and ideological awareness (Ruitenberg, 2009, p. 277).

Bringing all these views together and considering the latemodern risk society with all its socio-scientific and technological challenges, all domains of education need to contribute to critical literacy and a reflexive view on practice (i.e. praxis). We therefore suggest the critical-reflexive interpretation of *Bildung* as a metatheory for contemporary (science) education in the twenty-first century. This metatheory has, as will be shown in the next section,

consequences for the teaching and learning of science and also for the definition of scientific literacy (Sjöström & Eilks, *in press*).

Towards *Bildung*-oriented science education

Connecting Bildung with different visions of scientific literacy

There is little written about different ideological assumptions that underpin different formulations of science education, but Pedretti and Nazir (2015, p. 934) write: ‘a view that science education should be focused on teaching science content (a predominantly transmissive view) rather than focused on social reconstruction and change (a transformative view) can produce radically different experiences and challenges in the science classroom.’ This tension is related to the one between modernism and postmodernism in science education (Blades, 2008). It also mirrors a tension between views in traditional science education versus common views in environmental education (Dillon, 2014). Change-oriented science education includes values, worldviews, politicisation, and actions, and is connected to critical-reflexive *Bildung* as we have described it above (see also Sjöström, *in press*).

One of the politically set goals of science education is enabling *scientific literacy* in the learners. The concept of scientific literacy was coined in the USA in the late 1950s (Norris & Phillips, 2015), only shortly before the *Bildung*-concept in general went through a decay process, as described above. Scientific literacy has been used in several different ways since it was coined (Bybee, 2015). In his historical review of the concept, DeBoer (2000) suggested the broad goal of enhancing the public’s understanding and appreciation of science. Roberts (2007, 2011) has distinguished between two main visions of science education based on the understanding of the concept of scientific literacy: *Vision I* focuses on learning scientific content and scientific processes for later application, whereas *Vision II* focuses on learning for usefulness of scientific knowledge in life and society by starting science learning from meaningful applications and issues. This is in line with a differentiation of traditional vs. context-based science curricula (see e.g. Eilks, Rauch, Ralle, & Hofstein, 2013).

Wickman (2012, p. 488) described that the American concept of ‘literacy’ has started to replace the concept *Bildung* in the Scandinavian educational debate. He suggested the most probable reasons for this are both a dominating influence of Anglo-American educational research and the special attention to literacy in the international PISA studies. Consequently, Wickman, Liberg, and Östman (2012) connected scientific literacy with *Bildung* in a European sense. However, this is problematic because our analysis revealed, just like Fischler (2015) has stated, that *Bildung* cannot be interpreted as synonymous to scientific literacy. We suggest that the term ‘critical scientific literacy’ (Hodson, 2011) is more in line with *Bildung*-oriented science education, at least when *Bildung* is defined as critical-reflexive *Bildung*. Hodson uses critical scientific literacy as a short term for a critical scientific, technological and environmental literacy, i.e. critical literacy as defined above and with focus on the interplay between science, technology, society and environment. Other authors, e.g. Belova, Chang Rundgren, and Eilks (2015), have connected this idea with further educational objectives, e.g. with media education towards critical scientific media literacy.

As indicated, a more critically-oriented form of *Vision II* has started emerging e.g. by Hodson (2011). We have called it a *Vision III* of scientific literacy (e.g. Sjöström & Eilks, *in press*). Such a *Vision III* is connected to and based on the ideas of transformative learning, Education for Sustainability,

and critical-reflexive *Bildung*. If Vision II focuses on socialisation, Vision III goes one step further and focuses on emancipation. Dos Santos (2009, p. 362) writes: 'beyond the purpose of humanistic science education to prepare citizens for the technological society [Vision II], it is necessary to have a clearer view of science education as having sociopolitical function [Vision III].'

Visions of scientific literacy and democratic participation

Levinson (2010) has discussed and problematized what democratic participation can mean in relation to scientific literacy. He proposed four frameworks for describing socio-scientific democratic participation. Two of them are reactive (as in Vision II) and the other two – 'science education as praxis' and 'science education for conflict and dissent' – are radical and proactive (as in Vision III) in ways that reflect the tensions in the dominant discourses of scientific literacy and citizenship in school curricula.

The three visions of scientific literacy have the learning of and about science in common, but they accentuate different curriculum emphases: scientific content and knowledge about scientific processes (Vision I), usefulness and meaningfulness of science (Vision II), and science for individual and societal actions and transformations (Vision III), respectively (Sjöström & Eilks, *in press*). A *Vision III* of scientific literacy implies a politicised science education aiming at emancipation and societal participation, and includes aspects like socio- and eco-justice. Figure 1 attempts to portray a relationship between the three visions and the different versions of *Bildung*. We have labelled the three different approaches as *conceptual*, *contextual*, and *critical*, respectively. With 'critical' we mean both an awareness and critical stance towards the modern risk society and a more general moral-philosophical-existential-political approach (see also Gur-ze'ev, 2002). The discussion of the *Bildung* concept in this paper suggests that the conceptualisation of *Bildung* in the international science education literature should be a critical approach.

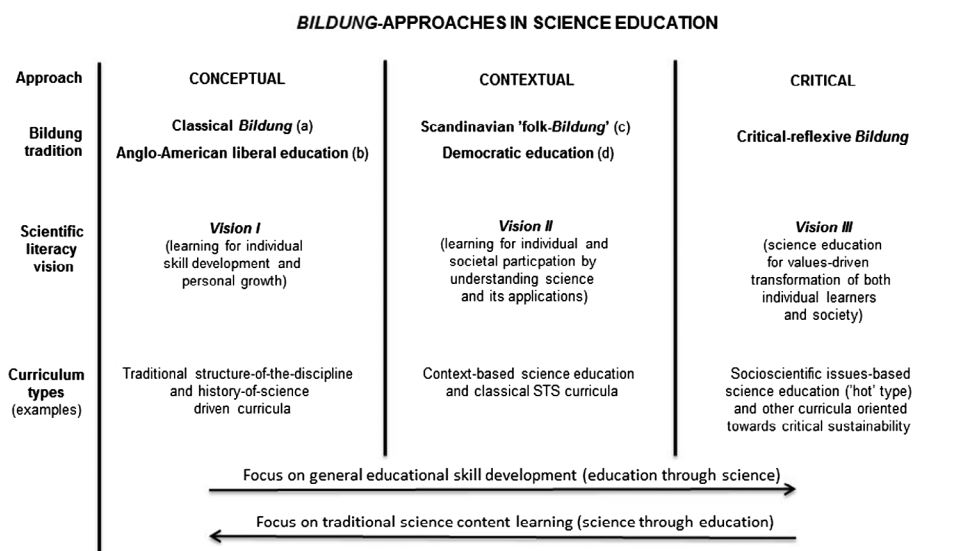


Figure 1. Different versions of *Bildung*-based science education.

Implications for science teaching and learning

Topics for critical scientific literacy/education are often related to domains like health, environment or risk technologies (Christensen, 2009); they are also often of a certain type. Most suitable examples might be complex SSIs. Sadler (2009, p. 523) suggested to select SSIs for science education 'which encourage personal connections between students and the issues discussed, explicitly address the value of justifying claims and expose the importance of attending to contradictory opinions.' Zeidler (2015) adds that SSIs are a conceptual framework used to guide theory, research, and practice in science education to fulfil the aim of fostering scientific literacy. This version of SSI emphasises relevance (both personally and societally), ethics, civic engagement and character formation (Zeidler & Sadler, 2008).

Complementing this sense of SSI, Stolz, Witteck, Marks, and Eilks (2013) have – with an explicit reference to *Bildung* – elaborated a set of five criteria for SSIs that have potential to lead to critical-reflexive science learning. They suggested that SSIs, for promotion of *Bildung* in science education, have to be (1) authentic, (2) relevant, (3) open with different potential decisions available in a socio-scientific respect, (4) offering the chance for open debate, and (5) connected to science and technology. Concerning authenticity they ask for authentic debates concerning SSIs, for documented SSIs in everyday-life media; for relevance whether there is any decision to be drawn that would make a difference so that any debate is worth having; for openness whether there are different points of view that are mirrored in positions by different stakeholders in the authentic debate on the individual or societal levels; for debatability whether debate is possible with exchanging arguments without harming single individuals with their views, cultural norms and values; and finally for connectedness to science and technology, whether there are arguments from science or technology used in the public debate or not. Based on this set they suggested implementing understanding of communication and decision-making practices about techno-scientific queries from society into the learning of science, e.g. by mimicking corresponding societal practices, such as using role play for mimicking societal debates, use business games for decision-making exercises, or creating newspaper articles to understand how SSIs are handled by individuals in society (Belova, Stuckey, Marks, & Eilks, 2015). Similar action-oriented SSIs have also been developed and described by Bencze (2017) and his co-workers.

'Hot type' versions of SSI, i.e. those emphasising transdisciplinarity, citizenship, and philosophical values (Simonneaux, 2014a, 2014b), are implicitly related to *Bildung*, although only explicitly in some works (e.g. Stolz et al., 2013). It is not fully clear, however, whether it is connected to 'democratic education' rather than to ideas like critical-reflexive *Bildung*. This issue is similar to Simonneaux's (2014a, 2014b) discussion about different curriculum orientations of SSI-education and Pedretti and Nazir's (2011) discussion about different orientations of STSE education. The uncertainty is also supported by the facts that the instructional paradigm of SSI by Sadler and Zeidler (2009) is described as 'progressive' and that they explicitly place themselves at Vision II of scientific literacy.

The SSI-criteria described above were derived from a model for a science curriculum by Marks and Eilks (2009), who describe it as socio-critical and problem-oriented science education. The model sets itself explicitly in a critical tradition of *Bildung*, since Klafki's *Allgemeinbildung* is given as the first instance of objectives. The curriculum model suggests moving over to mimicking authentic societal practice of communication and decision-making as essential parts of SSI-based science lessons with different pedagogies (Belova et al.,

2015), models e.g. based on the socio-philosophical works of Ludwik Fleck (1896–1961) (Stuckey, Heering, Mamlok-Naaman, Hofstein, & Eilks, 2015) and the idea of filtered information to understand how science is used and misused by different stakeholders in society (Hofstein et al., 2011).

Typical issues that are authentic, relevant, open-ended, debatable and science- and technology-based often stem from the environmental and sustainability debate (Marks et al., 2014; Sjöström, Rauch, & Eilks, 2015; Zuin & Pacca, 2013). According to a theoretical framework used by Zuin (2012) when analysing the environmentalization process in a public Brazilian Higher Education University for chemistry teacher education, *Bildung* is based on acquiring knowledge that remains in the memory, mobilising individuals to reshape and feel their practice according to what they have learned. These individuals, then, do not need external standards or principles to act ‘correctly’, because they know that non-reflected obedience of protocols or rules can abstain people from thinking carefully about the facts and contexts and, therefore, about themselves. So, educational processes which focus on socio-environmental sustainability must challenge blind obligations, restoring the historical character of all social production and not just the logic of instrumental rationality. The issues of climate change, ‘chemicalisation’ of our environment, renewable energy, materials supply, green engineering, sustainable agriculture, preserving biodiversity, or provision of clean water resources are only a few among many examples.

Concluding remarks

Bildung is a complex educational concept that started to emerge in Germany in the second half of the eighteenth century, based on a much longer history. The ideas behind *Bildung* underwent many changes and re-interpretations in central and northern Europe over the centuries. Different traditions emerged which became an indispensable part of central and northern European culture, and in the same time found parallels and relations in other parts of the world. However, it is only recently the concept of *Bildung* has found its way into the international discourse about the aims and orientations of science and environmental education.

To specify the meaning of *Bildung* today in general and for contemporary science education in particular, we have to make a ‘diagnosis’ of our time, which is a globalised risk society with many technological and ecological challenges. The ESD-movement has developed guiding principles for educational policy as well as challenges for classroom practice to make science education relevant for the young generation, also including trends related to green technologies. This process requires a re-orientation of the objectives of science education, both in its content and pedagogy. The idea of critical-reflexive *Bildung* offers a framework for this re-orientation.

In 2007 Roberts outlined his two visions of scientific literacy. Vision I was considered as teaching the content in natural science for later application, that is, the products of science itself. Roberts suggested that this approach only promotes literacy *within* science, but not about science. In his Vision II, scientific literacy should derive its meaning from situations with a scientific component, situations that students are likely to encounter as individuals and citizens. This second vision focuses learning *about* science, or about science-related situations. Although Roberts described these two visions as extremes, his Vision II does not necessarily include a strong focus on general skill development and transformation of the

individual and society for a sustainable future. Such a skillsets can be found in the debate about environmental and sustainability education, and is strongly supported by critical-reflexive *Bildung* and the *Vision III* of scientific literacy outlined above.

Stuckey et al. (2013) have analysed what constitutes the relevance of science teaching and learning. Their suggested model makes clear that all the three different visions of scientific literacy and their connections to different *Bildung* traditions can contribute to the relevance of science education. At the same time it shows that a neglect of preparation for societal participation concerning techno-scientific queries and issues of sustainability will limit the relevance of science learning. That means that science education needs a strong societal dimension and also should orient itself on the idea of general educational skill development. The suggested *Vision III* of scientific literacy includes such a view by claiming for science education with involvement of values, worldviews, politicisation, as well as actions.

Since *Bildung* is a concept that permeates all domains of education, it also concerns science education. This paper has shown that the concept is still largely neglected in the international science education literature. However, when used it is commonly used in line with the ideas of *Vision III*, as outlined above. We have argued that an incorporation of *Bildung* into the international discourse on science and environmental education suggests an explicit vision for transformative learning and sustainability education as outlined in our ideas of critical-reflexive *Bildung*. We have tried to articulate basic ideas for such a metatheory of (science) education and tried to describe its potential for praxis.

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

The references that were obtained during the literature review are starred.

AACU. (2007). *College learning for the new global century*. Washington, DC: Author.

*Aikenhead, G. S. (2006). *Science education for everyday life: Evidence-based practice*. New York, NY: Teachers College Press.

Albe, V. (2015). Science for citizenship. In R. Gunstone (Ed.), *Encyclopedia of science education* (pp. 904–905). Dordrecht: Springer.

Bauer, W. (2003). On the relevance of *Bildung* for democracy. *Educational Philosophy and Theory*, 35, 212–225.

Beck, U. (1992). *Risk society: Towards a new modernity*. Newbury Park: Sage.

Belova, N., Chang Rundgren, S.-N., & Eilks, I. (2015). Advertising and science education – A multi-perspective review of the literature. *Studies in Science Education*, 51, 169–200.

Belova, N., Stuckey, M., Marks, R., & Eilks, I. (2015). The idea of filtered information and the learning about the use of chemistry-related information in the public. In I. Eilks & A. Hofstein (Eds.), *Relevant chemistry education* (pp. 185–203). Rotterdam: Sense.

Bencze, L. (Ed.). (2017). *Science and technology education promoting wellbeing for individuals, societies and environments – STEPWISE*. Dordrecht: Springer.

*Bevilacqua, F., & Giannetto, E. (1996). The history of physics and European physics education. *Science & Education*, 5, 235–246.

Biesta, G. (2002a). *Bildung* and modernity: The future of *Bildung* in a world of difference. *Studies in Philosophy and Education*, 21, 343–351.

Biesta, G. (2002b). How general can *Bildung* be? Reflections on the future of a modern educational ideal. *Journal of Philosophy of Education*, 36, 377–390.

Biesta, G. (2012a). Becoming world-wise: An educational perspective on rhetorical curriculum. *Journal of Curriculum Studies*, 44, 815–826.

Biesta, G. (2012b). Have lifelong learning and emancipation still something to say to each other? *Studies in the Education of Adults*, 44, 5–20.

Biesta, G. (2013). Responsive or responsible? Democratic education for the global networked society. *Policy Futures in Education*, 11, 733–744.

Blades, D. (2008). Positive growth: Developments in the philosophy of science education. *Curriculum Inquiry*, 38, 387–399.

Bohlin, H. (2008). *Bildung* and moral self-cultivation in higher education: What does it mean and how can it be achieved? *Forum on Public Policy Online*, No. 2/2008, Retrieved January 10, 2015 from <https://forumonpublicpolicy.com/summer08papers/archivesummer08/bohlin.pdf>

Bohlin, H. (2013). *Bildung* and intercultural understanding. *Intercultural Education*, 24, 391–400.

*Bolte, C. (2008). A conceptual framework for the enhancement of popularity and relevance of science education for scientific literacy, based on stakeholders' views by means of a curricular Delphi study in chemistry. *Science Education International*, 19, 331–350.

Burman, A. (2011). Svar på frågan: Vad är medborgerlig bildning? [Answer on the question: What is civic-Bildung?] In A. Burman (Ed.), *Våga veta! Om bildningens möjligheter i massutbildningens tidevarv* [Dare to know! About the opportunities for Bildung in a time of mass education] (pp. 9–31). Huddinge: Södertörns högskola (in Swedish).

Burman, A. (2014). *Pedagogikens idéhistoria: Uppfostringsidéer och bildningsideal under 2500 år* [History of pedagogy: Ideas of education and ideals of Bildung during 2500 years]. Lund: Studentlitteratur (in Swedish).

Bybee, R. (2015). Scientific literacy. In R. Gunstone (Ed.), *Encyclopedia of science education* (pp. 944–947). Dordrecht: Springer.

Christensen, C. (2009). Risk and school science education. *Studies in Science Education*, 45, 205–223.

- *DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*, 37, 582–601.
- *DeBoer, G. E. (2011). The globalization of science education. *Journal of Research in Science Teaching*, 48, 567–591.
- Dillon, J. (2014). Environmental education. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (2nd ed.). (pp. 497–514). New York, NY: Routledge.
- Donnelly, J. F. (2004). Humanizing science education. *Science Education*, 88, 762–784.
- Dos Santos, W. L. P. (2009). Scientific literacy: A Freirean perspective as a radical view of humanistic science education. *Science Education*, 93, 361–382.
- *Duit, R. (2007). Science education research internationally: Conceptions, research methods, domains of research. *Eurasia Journal of Mathematics, Science & Technology Education*, 3, 3–15.
- Ebenezer, J. (2013). Social justice pedagogy for all science learners. *Studies in Science Education*, 49, 252–264.
- Eilks, I., Rauch, F., Ralle, B., & Hofstein, A. (2013). How to balance the chemistry curriculum between science and society. In I. Eilks & A. Hofstein (Eds.), *Teaching chemistry – A studybook* (pp. 1–36). Rotterdam: Sense.
- *Elmose, S., & Roth, W.-M. (2005). *Allgemeinbildung*: Readiness for living in risk society. *Journal of Curriculum Studies*, 37, 11–34.
- Fellenz, M. R. (2016). Forming the professional self: Bildung and the ontological perspective on professional education and development. *Educational Philosophy and Theory*, 48, 267–283.
- *Fensham, P. J. (2000). Providing suitable content in the ‘science for all’ curriculum. In R. Millar, J. Leach, & J. Osborne (Eds.), *Improving science education* (pp. 147–164). Buckingham: Open University Press.
- *Fensham, P. J. (2004). *Defining an identity*. Dordrecht: Kluwer.
- *Fensham, P. J. (2009). The link between policy and practice in science education: The role of research. *Science Education*, 93, 1076–1095.
- Fischer, E. P. (2001). *Die andere Bildung* [The other Bildung]. München: Ullstein (in German).
- *Fischler, H. (2011). Didaktik – An appropriate framework for the professional work of science teachers? In D. Corrigan, J. Dillon, & R. Gunstone (Eds.), *The professional knowledge base of science teaching* (pp. 31–50). Dordrecht: Springer.
- Fischler, H. (2015). Bildung. In R. Gunstone (Ed.), *Encyclopedia of science education* (pp. 118–122). Dordrecht: Springer.
- Galloway, S. (2012). Reconsidering emancipatory education: Staging a conversation between Paulo Freire and Jacques Rancière. *Educational Theory*, 62, 163–184.
- *Gundem, B. B., & Hopmann, S. (2002). *Didaktik and/or curriculum: An international dialogue*. New York, NY: Peter Lang.
- Gur-ze'ev, I. (2002). Bildung and critical theory in the face of postmodern education. *Journal of Philosophy of Education*, 36, 391–408.
- Gustafsson, B. (2006). *Bildning och fysik: Vad betyder vävens mönster?* [Bildung and physics: What does the patterns of the web mean?]. Rapport 2006:50R, Swedish National Agency for Higher Education (in Swedish).
- Gustavsson, B. (2012). *Bildningens traditioner i transformation* [The traditions of Bildung in transformation]. In A. Burman & P. Sundgren (Eds.), *Svenska bildningstraditioner* [Swedish Bildung traditions] (pp. 309–327). Göteborg: Daidalos (in Swedish).
- Gustavsson, B. (2014). Bildung and the road from a classical into a global and postcolonial concept. *Confero*, 2, 109–131.
- Hadzigeorgiou, Y. (2015). A critique of science education as sociopolitical action from the perspective of liberal education. *Science & Education*, 24, 259–280.
- *Hansen, K. H., & Olson, J. (1996). How teachers construe curriculum integration: The science, technology, society (STS) movement as Bildung. *Journal of Curriculum Studies*, 28, 669–682.
- Hodson, D. (1998). *Teaching and learning science: Towards a personalized approach*. Philadelphia, PA: Open University Press.
- Hodson, D. (2011). *Looking to the future: Building a curriculum for social activism*. Rotterdam: Sense.

- *Hofstein, A., Eilks, I., & Bybee, R. (2011). Societal issues and their importance for contemporary science education: A pedagogical justification and the state of the art in Israel, Germany and the USA. *International Journal of Science and Mathematics Education*, 9, 1459–1483.
- Horlacher, R. (2012). What is *Bildung*? or why *Pädagogik* cannot get away from the concept of *Bildung*. In P. Siljander, A. Kivelä, & A. Sutinen (Eds.), *Theories of Bildung and growth* (pp. 135–147). Rotterdam: Sense.
- Horlacher, R. (2016). *The educated subject and the German concept of Bildung – A comparative cultural history*. London: Routledge.
- Huckle, J., & Wals, A. E. J. (2015). The UN decade of education for sustainable development: Business as usual in the end. *Environmental Education Research*, 21, 491–505.
- Jickling, B., & Wals, A. E. J. (2008). Globalization and environmental education: Looking beyond sustainable development. *Journal of Curriculum Studies*, 40, 1–21.
- Johnson, L., & Morris, P. (2010). Towards a framework for critical citizenship education. *The Curriculum Journal*, 21, 77–96.
- Kemp, P. (2005, in English 2010). *Världsmedborgaren: Politisk och pedagogisk filosofi för det 21 århundradet* [Citizen of the World: Cosmopolitan Ideals for the 21st Century]. Göteborg: Daidalos (in Swedish).
- Kivelä, A., Siljander, P., & Sutinen, A. (2012). Between *Bildung* and growth: Connections and controversies. In P. Siljander, A. Kivelä, & A. Sutinen (Eds.), *Theories of Bildung and growth* (pp. 303–312). Rotterdam: Sense.
- Klafki, W. (2000). The significance of classical theories of *Bildung* for a contemporary concept of Allgemeinbildung. In I. Westbury, S. Hopmann, & K. Riquarts (Eds.), *Teaching as a reflective practice: The German Didaktik tradition* (pp. 85–108). Mahwah: Lawrence Erlbaum.
- Kopnina, H. (2014). Future scenarios and environmental education. *The Journal of Environmental Education*, 45, 217–231.
- *Krageskov Eriksen, K. (2002). The future of tertiary chemical education – A *Bildung* focus. *HYLE – International Journal for Philosophy of Chemistry*, 8, 35–48.
- *Læssøe, J. (2010). Education for sustainable development, participation and socio-cultural change. *Environmental Education Research*, 16, 39–57.
- Latour, B. (2004). Why has critique run out of steam? From matters of fact to matters of concern. *Critical Inquiry*, 30, 225–248.
- Levinson, R. (2010). Science education and democratic participation: An uneasy congruence? *Studies in Science Education*, 46, 69–119.
- Lewinson, M., Flint, A. S., & Van Sluys, K. (2002). Taking on critical literacy: The journey of newcomers and novices. *Language Arts*, 79, 382–392.
- Liedman, S.-E. (1997). *I skuggan av framtiden – Modernitetens idéhistoria* [In the shadow of the future – History of modernity]. Stockholm: Albert Bonniers Förlag (in Swedish).
- Liedman, S.-E. (2001). *Ett oändligt äventyr – Om människans kunskaper* [An endless adventure – About the knowledge of human beings]. Stockholm: Albert Bonniers Förlag (in Swedish).
- Løvlie, L., & Standish, P. (2002). Introduction: *Bildung* and the idea of a liberal education. *Journal of Philosophy of Education*, 36, 317–340.
- Mannion, G., Biesta, G., Priestley, M., & Ross, H. (2011). The global dimension in education and education for global citizenship: Genealogy and critique. *Globalisation, Societies and Education*, 9, 443–456.
- Marks, R., & Eilks, I. (2009). Promoting scientific literacy using a socio-critical and problem-oriented approach to chemistry teaching: Concept, examples, experiences. *International Journal of Environmental and Science Education*, 4, 131–145.
- Marks, R., Stuckey, M., Belova, N., & Eilks, I. (2014). The societal dimension in German science education – From tradition towards selected cases and recent developments. *Eurasia Journal of Mathematics, Science & Technology Education*, 10, 285–296.
- Masschelein, J., & Ricken, N. (2003). Do we (still) need the concept of *Bildung*? *Educational Philosophy and Theory*, 35, 139–154.
- Matthews, M. R. (1994). *Science teaching: The role of history and philosophy of science*. Hove: Psychology Press.
- Matthews, M. R. (2000). *Time for science education: How teaching the history and philosophy of pendulum motion can contribute to scientific literacy*. New York, NY: Kluwer.

- *Mogensen, F., & Schnack, K. (2010). The action competence approach and the 'new' discourses of education for sustainable development, competence and quality criteria. *Environmental Education Research*, 16, 59–74.
- *Neumann, K., Fischer, H. E., & Kauertz, A. (2010). From PISA to educational standards: The impact of large-scale assessments on science education in Germany. *International Journal of Science and Mathematics Education*, 8, 545–563.
- Nilsson, S. (Ed.) (2010). *Naturvetenskaplig bildning* [Scientific Bildung]. Grundtviginstitutet vid Göteborgs universitet skriftserie nr. 9, Göteborgs universitet (in Swedish). Retrieved February 17, 2017 from www.ufn.gu.se/digitalAssets/1326/1326262_rap
- Nohl, A. M. (2009). Spontaneous action and transformative learning: Empirical investigations and pragmatist reflections. *Educational Philosophy and Theory*, 41, 287–306.
- Nordenbo, S. E. (2002). *Bildung* and the thinking of *Bildung*. *Journal of Philosophy of Education*, 36, 341–352.
- Norris, S., & Phillips, L. M. (2015). Scientific literacy: Its relationship to 'literacy'. In R. Gunstone (Ed.), *Encyclopedia of science education* (pp. 947–950). Dordrecht: Springer.
- Paulsen, A. C. (2006). Naturfag i skolen i et kritisk demokratisk dannelseperspektiv [Science subjects in school in a critical-democratic Bildung-perspective]. *NorDiNa: Nordic Studies in Science Education*, 4, 69–84 (in Danish).
- Pedretti, E., & Nazir, J. (2011). Currents in STSE education: Mapping a complex field, 40 years on. *Science Education*, 95, 601–626.
- Pedretti, E., & Nazir, J. (2015). Science, technology and society (STS). In R. Gunstone (Ed.), *Encyclopedia of science education* (pp. 932–935). Dordrecht: Springer.
- Peukert, H. (2002). Beyond the present state of affairs: *Bildung* and the search for orientation in rapidly transforming societies. *Journal of Philosophy of Education*, 36, 421–435.
- Reichenbach, R. (2002). On irritation and transformation: A-teleological *Bildung* and its significance for the democratic form of living. *Journal of Philosophy of Education*, 36, 409–419.
- Reichenbach, R. (2014). *Humanistic Bildung*: Regulative idea or empty concept? *Asia Pacific Education Review*, 15, 65–70.
- Reichenbach, R. (2016). "The source of learning is thought" reading the *Chin-ssu lu* (近思錄) with a "Western Eye". *Educational Philosophy and Theory*, 48, 36–51.
- Retter, H. (2012). Dewey's progressive education, experience and instrumental pragmatism with particular reference to the concept of *Bildung*. In P. Siljander, A. Kivelä, & A. Sutinen (Eds.), *Theories of Bildung and growth* (pp. 281–302). Rotterdam: Sense.
- Roberts, D. A. (2007). Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 729–780). Mahwah: Lawrence Erlbaum.
- Roberts, D. A. (2011). Competing visions of scientific literacy: The influence of a science curriculum policy image. In C. Linder, L. Östman, D. A. Roberts, P.-O. Wickman, G. Erickson, & A. MacKinnon (Eds.), *Exploring the landscape of scientific literacy* (pp. 11–27). London: Routledge.
- Roth, W.-M., & Calabrese Barton, A. (2004). *Rethinking scientific literacy*. New York, NY: Routledge.
- Rucker, T., & Gerónimo, E. D. (2017). The problem of *Bildung* and the basic structure of *Bildungstheorie*. *Studies in Philosophy and Education*, 36, 569–584.
- Ruitenbergh, C. W. (2009). Educating political adversaries: Chantal Mouffe and radical democratic citizenship education. *Studies in Philosophy and Education*, 28, 269–281.
- Sadler, T. D. (2009). Situated learning in science education: Socio-scientific issues as contexts for practice. *Studies in Science Education*, 45, 1–42.
- Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, 46, 909–921.
- Säfström, C. A. (2011). Rethinking emancipation, rethinking education. *Studies in Philosophy and Education*, 30, 199–209.
- Schaffar, B., & Uljens, M. (2015). Paradoxical tensions between *Bildung* and *Ausbildung* in academia: Moving within or beyond the modern continental tradition. In E. Westergaard & J. S. Wiewiura (Eds.), *On the facilitation of the academy* (pp. 1–15). Rotterdam: Sense.

- *Schnack, K. (2008). Participation, education, and democracy: Implications for environmental education, health education, and education for sustainable development. In A. Reid, B. B. Jensen, J. Nikel, & V. Simovska (Eds.), *Participation and learning* (pp. 181–196). Dordrecht: Springer.
- Schneider, K. (2012). The subject-object transformations and 'Bildung'. *Educational Philosophy and Theory*, 44, 302–311.
- Schulz, R. M. (2009). Reforming science education: Part I. The search for a philosophy of science education. *Science & Education*, 18, 225–249.
- Schulz, R. M. (2014a). *Rethinking science education: Philosophical perspectives*. Charlotte, NC: Information Age Publishing.
- *Schulz, R. M. (2014b). Philosophy of education and science education: A vital but underdeveloped relationship. In M. Matthews (Ed.), *International handbook of research in history, philosophy and science teaching* (pp. 1259–1316). Dordrecht: Springer.
- Schwanitz, D. (1999). *Bildung – alles was man wissen muss* [Bildung – Everything one has to know]. Frankfurt: Eichborn (in German).
- Sim, J. B. Y., & Ling Low, E. (2012). Character and citizenship education: Conversations between personal and societal values. *Asia Pacific Journal of Education*, 32, 381–394.
- Simonneaux, L. (2014a). *Questions socialement vives* and socio-scientific issues: New trends of research to meet the training needs of postmodern society. In C. Bruguère, A. Tiberghien, & P. Clement (Eds.), *Topics and trends in current science education* (pp. 37–54). Dordrecht: Springer.
- Simonneaux, L. (2014b). From promoting the techno-sciences to activism – A variety of objectives involved in the teaching of SSIs. In L. Bencze & S. Alsop (Eds.), *Activist science and technology education* (pp. 99–111). Dordrecht: Springer.
- Simonneaux, J., & Simonneaux, L. (2012). Educational configurations for teaching environmental socioscientific issues within the perspective of sustainability. *Research in Science Education*, 42, 75–94.
- *Sjøberg, S. (1997). Scientific literacy and school science – Arguments and second thoughts. In S. Sjøberg & E. Kallerud (Eds.), *Science, technology and citizenship* (Vol. 7/97, pp. 9–28). Oslo: Norsk institutt for studier av forskning og utdanning.
- Sjøberg, S. (1998). *Naturfag som allmenndannelse – en kritisk fagdidaktikk* [Science as part of Bildung for all – A critical subject-Didaktik]. Oslo: Gyldendal (in Norwegian).
- *Sjøberg, S. (2002). Science and technology education: Current challenges and possible solutions. *Innovations in Science and Technology Education*, 8, 296–307.
- Sjöström, J. (2007). The discourse of chemistry (and beyond). *HYLE – International Journal for Philosophy of Chemistry*, 13, 83–97.
- *Sjöström, J. (2013). Towards *Bildung*-oriented chemistry education. *Science & Education*, 22, 1873–1890.
- Sjöström, J. (in press). Science teacher identity and eco-transformation of science education: Comparing western modernism with Confucianism and reflexive *Bildung*. *Cultural Studies of Science Education*. doi:10.1007/s11422-016-9802-0
- Sjöström, J., & Eilks, I. (in press). Reconsidering different visions of scientific literacy and science education based on the concept of *Bildung*. In Y. J. Dori, Z. Mevarech, & D. Baker (Eds.), *Cognition, metacognition, and culture in STEM education*. Dordrecht: Springer.
- Sjöström, J., & Talanquer, V. (2014). Humanizing chemistry education: From simple contextualization to multifaceted problematization. *Journal of Chemical Education*, 91, 1125–1131.
- Sjöström, J., Rauch, F., & Eilks, I. (2015). Chemistry education for sustainability. In I. Eilks & A. Hofstein (Eds.), *Relevant chemistry education* (pp. 163–184). Rotterdam: Sense.
- *Sjöström, J., Eilks, I., & Zuin, V. G. (2016). Towards eco-reflexive science education: A critical reflection about educational implications of green chemistry. *Science & Education*, 25, 321–341.
- Staeheli, L. A., & Hammett, D. (2010). Educating the new national citizen: Education, political subjectivity and divided societies. *Citizenship Studies*, 14, 667–680.
- *Ståhl, M., & Hussénus, A. (2017). Chemistry inside an epistemological community box! Discursive exclusions and inclusions in Swedish National tests in Chemistry. *Cultural Studies of Science Education*, 12, 395–423.
- Sterling, S. (2011). Transformative learning and sustainability: Sketching the conceptual ground. *Learning and Teaching in Higher Education*, 5, 17–33.

- Stolz, M., Witteck, T., Marks, R., & Eilks, I. (2013). Reflecting socio-scientific issues for science education coming from the case of curriculum development on doping in chemistry education. *Eurasia Journal of Mathematics, Science and Technological Education*, 9, 273–282.
- *Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of ‘relevance’ in science education and its implications for the science curriculum. *Studies in Science Education*, 49, 1–34.
- Stuckey, M., Heering, P., Mamlok-Naaman, R., Hofstein, A., & Eilks, I. (2015). The philosophy of Ludwik Fleck and its potential meaning for the teaching and learning of science. *Science & Education*, 24, 281–298.
- Taylor, C. A. (2017). Is a posthumanist *Bildung* possible? Reclaiming the promise of *Bildung* for contemporary higher education. *Higher Education*, 74, 419–435.
- Thomas, I. (2009). Critical thinking, transformative learning, sustainable education, and problem-based learning in universities. *Journal of Transformative Education*, 7, 245–264.
- Thompson, C. (2005). The non-transparency of the self and the ethical value of *Bildung*. *Journal of Philosophy of Education*, 39, 519–533.
- Väkevä, L. (2012). Experiencing growth as a natural phenomenon: John Dewey’s philosophy and the *Bildung* tradition. In P. Siljander, A. Kivelä, & A. Sutinen (Eds.), *Theories of Bildung and growth* (pp. 261–279). Rotterdam: Sense.
- *Van Dijk, E. M., & Kattmann, U. (2007). A research model for the study of science teachers’ PCK and improving teacher education. *Teaching and Teacher Education*, 23, 885–897.
- Van Poeck, K., & Vandenabeele, J. (2012). Learning from sustainable development: Education in the light of public issues. *Environmental Education Research*, 18, 541–552.
- Van Poeck, K., Goeminne, G., & Vandenabeele, J. (2016). Revisiting the democratic paradox of environmental and sustainability education: Sustainability issues as matters of concern. *Environmental Education Research*, 22, 806–826.
- Vásquez-Levy, D. (2002). *Bildung*-centred Didaktik: a framework for examining the educational potential of subject matter. *Journal of Curriculum Studies*, 34, 117–128.
- Von Humboldt, W. (2000). Theory of *Bildung*. In I. Westbury, S. Hopmann, & K. Riquarts (Eds.), *Teaching as a reflective practice: The German Didaktik tradition* (pp. 57–62). Mahwah: Lawrence Erlbaum.
- Wagenschein, M. (2000). The law of free fall as an “exemplary theme” for the mathematicizability of certain natural processes. In I. Westbury, S. Hopmann, & K. Riquarts (Eds.), *Teaching as a reflective practice: The German Didaktik tradition* (pp. 285–294). Mahwah: Lawrence Erlbaum.
- Weaver, J., Morris, M., & Appelbaum, P. (2001). *(Post) modern science (education)*. New York, NY: Peter Lang.
- *Westbury, I. (2000). Teaching as a reflective practice: What might Didaktik teach curriculum? In I. Westbury, S. Hopmann, & K. Riquarts (Eds.), *Teaching as a reflective practice: The German Didaktik tradition* (pp. 15–39). Mahwah: Lawrence Erlbaum.
- *Westbury, I., Hopmann, S., & Riquarts, K. (Eds.). (2000). *Teaching as a reflective practice: The German Didaktik tradition*. Mahwah: Lawrence Erlbaum.
- Wickman, P.-O. (2012). Using pragmatism to develop didactics in Sweden. *Zeitschrift für Erziehungswissenschaft*, 15, 483–501.
- Wickman, P.-O., Liberg, C., & Östman, L. (2012). Transcending science: Scientific literacy and *Bildung* for the 21st century. In D. Jorde & J. Dillon (Eds.), *Science education research and practice in Europe* (pp. 39–61). Rotterdam: Sense.
- Willbergh, I. (2015). The problems of ‘competence’ and alternatives from the Scandinavian perspective of *Bildung*. *Journal of Curriculum Studies*, 47, 334–354.
- Wimmer, M. (2003). Ruins of *Bildung* in a knowledge society: Commenting on the debate about future of *Bildung*. *Educational Philosophy and Theory*, 35, 167–187.
- *Witz, K. G., & Lee, H. (2009). Science as an ideal: Teachers’ orientations to science and science education reform. *Journal of Curriculum Studies*, 41, 409–431.
- Zeidler, D. (2015). Socioscientific issues. In R. Gunstone (Ed.), *Encyclopedia of science education* (pp. 998–1003). Dordrecht: Springer.

- Zeidler, D. L., & Sadler, T. D. (2008). The role of moral reasoning in argumentation: Conscience, character and care. In S. Erduran & P. Jimenez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp. 201–216). Dordrecht: Springer.
- Zembylas, M. (2006). Science education as emancipatory: The case of Roy Bhaskar's philosophy of meta-reality. *Educational Philosophy and Theory*, 38, 665–676.
- Zuin, V. G. (2012). *Environmental dimension in chemistry teacher education*. Campinas: Alínea.
- Zuin, V. G., & Pacca, J. L. A. (2013). Formação docente em Química y ambientación curricular: Estudio de caso em uma instituição de enseñanza Brasileira [Formation of teachers in chemistry and curricular environmentalization: A case study in a tertiary education institution in Brazil]. *Enseñanza de las Ciencias*, 31, 77–91 (in Portuguese).