Chapter 4
Reconsidering Different Visions of Scientific Literacy and Science Education Based on the Concept of *Bildung*

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4.1 Introduction

Over the last 50 years, policy makers and STEM educators have argued for Scientific Literacy (SL) (Roberts 2007). SL has become a guiding framework in educational policy, for example, in the PISA studies (Sadler and Zeidler 2009). Laugksch (2000) has stated that SL has become a buzzword, conveying a rather vague notion of what the general public should know about science. However, there have been a number of attempts to systematically describe different elements of SL (e.g., Coll and Taylor 2009; Gräber and Bolte 1997). One example is Hodson (2009), who subdivided scientific and technological literacy into the following three elements:

1. Learning science and technology (e.g., conceptual understanding);
2. Doing science and technology (e.g., scientific inquiry); and
3. Learning *about* science and technology.

Roberts (2007, 2011) distinguished between two main orientations of SL: *Vision I*, which focuses mainly on learning about scientific content and scientific processes for later application, and *Vision II*, which focuses on understanding the usefulness

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of scientific knowledge in life and society by starting science learning from meaningful contexts. The tension between Vision I and II is related to the tension between "pipeline science – preparing future scientists" and "science for all" (Aikenhead 2006), but these two visions can also be seen as two different orientations of the science curriculum (Eilks et al. 2013).

Recently, a more advanced form of Vision II was suggested, called *Vision III,* which emphasizes scientific engagement (Liu 2013; Yore 2012) and "knowing-in-action" (Aikenhead 2007). As far as we know, Hodson (2003, 2009, 2011) did not use the term Vision III. But instead he used the term "critical scientific literacy", and added a forth element in addition to the three mentioned above: Engaging in socio-political action. Similarly, Santos (2009) has identified three types of SL, which can be described as: (a) practical view, (b) understanding human culture and (c) socio-political action.

Vision III or critical-SL can be understood based on the Central/Northern European educational tradition called *Bildung* (Hofstein et al. 2011; Sjöström 2013a). *Bildung* is a complex concept that can – as discussed further below – be explained in several ways, but typically it consists of two elements: an ideal picture (of desirable knowledge and cognitive skills) and free learning processes (Gustavsson 2014a), or in other words both "the process of personal development and the result of this development process" (Fischler 2011, p. 33). Schneider (2012) describes *Bildung* as a reflexive event and its function is to form the self in a complex meaning-making process that covers the whole range from early childhood to the advanced age. According to Wimmer (2003), *Bildung* encompasses all aims that are not covered by other concepts of pedagogical theory, such as socialisation, education, and instruction; it stands for them all and provides also something more. He describes it as "the central critical concept of modern pedagogy" (p. 185). Due to its both educational and political dimensions (Biesta 2002a), it allows us to say something different about science education and scientific literacy.

In general, one can say that *Bildung*-oriented science education is an example of humanized science education (Aikenhead 2006) that goes beyond many understandings of scientific literacy in the literature. However, it has many similarities with "science for [critical] citizenship" (e.g., Albe 2015), complex versions of socio-scientific issues (SSI) based science education (e.g., Bencze et al. 2012; Simonneaux and Simonneaux 2012; Zeidler 2015) and STSE (Science, Technology, Society, and Environment) education (e.g., Pedretti and Nazir 2011).

Similar to us, Wickman et al. (2012) connected scientific literacy in the European sense with *Bildung* (see also Fischler 2015) and Elmose and Roth (2005) tried to introduce the concept of *Bildung* to justify science teaching focusing on preparing students for political participation in a growing complex world. However, these papers are not explicitly discussing a Vision III of scientific literacy (i.e., critical-SL), and put no direct emphasis on educated socio-political action. But the definition by Wickman et al. emphasizes the importance of worldviews, values and ethics in science education. Similarly, such socio-cultural aspects were emphasized by Sadler and Zeidler (2009) in their SSI framework; regarding SL it is interesting that they explicitly placed themselves at the extreme of Vision II.

In this chapter it is suggested that SL and *Bildung* should be considered to be action-oriented – or even better, 'praxis-oriented'. *Bildung*-oriented education aims

at making the student capable for a self-determined life in his/her socio-cultural environment, for participation in a democratic society, and for empathy and solidarity with others (e.g., Elmose and Roth 2005; Hofstein et al. 2011; Sjöström 2013a). In other words, Vision III of SL should imply a politicised science education aiming at emancipation and socio-ecojustice. This concept is also closely connected to more recent educational paradigms, for example, the ideas of Education for Sustainability (EfS) (Sjöström et al. 2015) and transformative learning (Mezirow 1997; Sterling 2011; Thomas 2009), where content and contexts should be considered from multifaceted perspectives. EfS aims on skills development for critical-democratic participation and for shaping society in a sustainable way. Simonneaux (2014a) emphasises participation and action as especially important parts of transformative science education: "when implementing post-normal education, it is not sufficient just to learn and to understand. Instead, the central purpose is to encourage participation and action in the scientific activity." (p. 51)

In other words, the different visions of SL have consequences for the teaching and learning in the STEM subjects. Within a *Bildung*-tradition there is awareness that our view of scientific content knowledge is dependent on our culture, for example our norms, values and worldviews, and it is dependent on the time we are living in (Sjöström 2013a). Furthermore, there is an awareness that learning (cognition) must be complemented with not only meta-learning (metacognition), but also with epistemic and transformative learning (Sterling 2011). Examples include scientific concepts and models, but also scientific processes (nature of science, NOS) and the embeddedness of science and technology in society (Sjöström and Talanquer 2014).

To summarize this chapter focuses on implications for science teaching and learning of *Vision III* of SL and its connection to a contemporary understanding of *Bildung,* EfS and transformative learning. We start with describing the concept of *Bildung*, focusing on the most complex type, which we call critical-reflexive *Bildung*. Thereafter, we first discuss implications of this version of *Bildung* on education in general and then its connection to different meanings of 'critical' in education. It is followed by in-depth discussions of implications of critical-reflexive *Bildung* on science education and scientific literacy, respectively.

4.2 The Concept of *Bildung*

In Central and Northern Europe (especially in German speaking countries and in Scandinavia) there is a philosophical-educational tradition called *Bildung*, which has been developed since the late eighteenth century by Johann Gottfried Herder, Wilhelm von Humboldt, Hans-Georg Gadamer, Erich Weniger, Wolfgang Klafki and others.[1] Because there is no precise English translation, the German term *Bildung* started to be used in the international educational literature (e.g., Elmose and Roth 2005; Hofstein et al. 2011; Sjöström 2013a).

[1] See (Westbury et al. 2000), for some translated original contributions from the history of *Bildung* and *Didaktik* in Central Europe.

Without doubt *Bildung* is a complex construct and a description of its genesis may help understanding the concept. According to Gustavsson (2012, 2014a) at least three versions of *Bildung* are well-established today and all of them have transformed over time from a national/European to a global focus. We call them (a) classical *Bildung*, (b) Anglo-American *Bildung*, or liberal education, and (e) critical-reflexive *Bildung*. In addition to these three versions Burman (2011) also identified two civic-oriented *Bildung*-traditions: (c) the Scandinavian folk-Bildung-tradition, and (d) Dewey's democratic education. In the following we will describe these five *Bildung*-traditions in a little more detail:

(a) *Classical Bildung:* this tradition is based on the German philosopher and educational politician Wilhelm von Humboldt (1767–1835) (2000, originally in German, 1793). Von Humboldt understood *Bildung* as "one in the tradition rooted process of individualization where humans through studies and reflections develop their personality 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 at universities – more associated with free search for knowledge, free from both the state and the market. The works of von Humboldt are also sometimes misused. His idea that *Bildung* manifests itself mainly in language, led to a long time of devaluing the sciences for developing own worldviews in the individual. In some European countries, e.g. Sweden and Germany, this led to a long time of over-emphasizing the humanities to constitute classical *Bildung* against education in the STEM subjects.

(b) *Anglo-American Bildung:* the thoughts behind this tradition, which is called liberal education, can also be tracked back to von Humboldt (Løvlie and Standish 2002). The character-formation ideal is emphasized in the English version, whereas the canon was emphasized in the American version (Burman 2014). The latter has strong connections to American colleges. The liberal education tradition emphasizes humanism and generalization – in contrast to specialization – and also, that education must be free from short-term instrumental thinking. The thought of life-long learning, which for example is important in contemporary European policy debate, is related to this type of thinking. A famous representative for a more critical and cosmopolitical version of liberal education is Martha Nussbaum (born 1947). She argues for ethical self-reflection and critical approaches to the own culture and its traditions. This is needed to create enlightened citizens, rather than efficient workers and uncritical consumers. Nussbaum uses typical *Bildung*-type arguments for liberal education, however without explicitly using the term (Bohlin 2008).

(c) *The Scandinavian folk-Bildung-tradition*: from the late nineteenth century a unique tradition called *folkbildning* in Swedish (might be translated as '*Bildung* for the whole people') was developed in Scandinavia. It is a tradition that is less

academically oriented than the classical German tradition. The German basic notion was combined with a pronounced benefit-approach. *Bildung* should be useful for the creation of a society with justice. The political dimension was much more explicit than in the classical German version, but it was not especially radical. An example of a famous Swedish pedagogue is Ellen Key (1849–1926). She emphasized *Bildung* as a relevant concept both on the individual and the societal level. Children should be educated to become civic citizens. School would encourage students to become free, responsible actors in society, with a developed individuality – cognitively, morally, as well as aesthetically (Burman 2014).

(d) *Dewey's democratic education*: the idea of a school for all was also developed in the USA by John Dewey (1859–1952). In the book *Democracy and Education: An Introduction to the Philosophy of Education* from 1916 he advocated that school has a crucial role to play in every democratic society. He suggested the basic mission of school is to prepare for citizenship. This requires that students can develop quite freely (Burman 2014). According to Väkevä (2012), Dewey's most important contribution to the *Bildung* tradition was his analysis of the social-ethical foundations of a society to promote democratic habits. Dewey used the term *Bildung* in his work, although not systematically (Bauer 2003). However, it is interesting that Kivelä et al. (2012) conclude that on a general level there is no significant difference between *Bildung* (in a growth-theoretical understanding) and the ideas of pragmatists such as Dewey, James, and Mead.

(e) *Critical-reflexive Bildung*: this understanding of *Bildung* is rooted in the work by Hans-Georg Gadamer (1900–2002) and Paul Ricoeur (1913–2005) and can be described with '*Bildung* as a journey' (Gustavsson 2012, 2014a). Especially during the 1950s and 1960s, and in interaction with the work of Gadamer and Ricoeur, the German educational philosophers Erich Weniger (1894–1961) and Wolfgang Klafki (1927–2016) developed a new understanding of *Bildung* connected to educational practice. They created 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 Scandinavian approach of *folkbildning*). The second dimension aims at *Bildung* in all human capacities (e.g., Klafki 2000a). Klafki's thinking is based on the thought that responsible citizens in a democratic society need *Bildung*. This educational philosophy has a clear critical approach (see further below) and we regard critical-reflexive *Bildung* the most complex version of the five traditions. In the following, when the term *Bildung* is used, we mean this version, if not something else is specified.

4.3 Critical-Constructive *Didaktik* as an Educational Implication of *Bildung*

Bildung in a critical understanding is praxis-oriented, in addition to being oriented towards consciousness and critical literacy. In line with this, Mogensen and Schnack (2010, p. 60) argue that their concept of 'action competence' is "closely linked to democratic, political education and to […] the notion of '*Bildung*'." According to Marks et al. (2014, p. 286), *Bildung* "…inseparably bounds education to a democratic understanding of society. It defines all objectives of education under consideration of a societal perspective, for education in general, but also for all school educational domains in particular – among them science education."

For educational operation Klafki (2000b, originally in German, 1958; see also Fischler 2011) and others developed a tool called *Didactical Analysis* as being part of the so called *Critical-Constructive Didaktik*. At this point it is necessary to say that the *Bildung*-connected meaning of the term *Didaktik* in German and Scandinavian languages differs a lot from how the word *didactics* is used in English (Duit 2015). *Didaktik* in German and Scandinavian languages means the knowledge about teaching and learning and at the same time covers the research area about teaching and learning (Hopmann 2007; Kansanen 2009). According to Duit (2015, p. 325) *Didaktik* "stands for a multifaceted view of planning and performing instruction. It is based on the German concept of *Bildung* [… and] concerns the analytical process of transposing (and transforming) human knowledge (the cultural heritage) into knowledge for schooling that contributes to Bildung". Hopmann (2007, p. 109) has compared *Didaktik* and the Anglo-American concept of curriculum and instruction. He claims that "Didaktik is characterized as 'restrained teaching', based on (a) a commitment to Bildung, (b) the educative difference of matter and meaning, and (c) the autonomy of teaching and learning." Similarly, Kansanen (2009) compared subject-matter didactics with Lee Shulman's pedagogical content knowledge (PCK). The former is, according to Kansanen, a much broader idea also containing aspects of values and other characteristics related to the curriculum and pedagogy. The *Didaktik* tradition focuses predominantly on the *why*-question (and its implication on practice), while the pragmatic Anglo-American curriculum tradition focuses more on the *how*-question (Duit 2015).

Didactical Analysis in terms of Klafki reflects whether an issue or topic is relevant enough to be taught. It consists of a set of certain questions, e.g. what the general exemplary character of the topic is, or what meaning it has for the learner today and for his/her future (Klafki 2000b, published originally in German 1958). These questions try to identify epoch-typical relevant knowledge and key problems to learn about, which are of importance for the individuals and the society the students live in and operate today and in the future. Contemporary examples of science-related key problems, important for education, are among many others e.g. the questions of global warming (Selby 2014), alternative energy usages (Feierabend and Eilks 2011), or the *chemicalization* of our world (Sjöström and Stenborg 2014). Except learning the science behind such relevant issues, students also should get

"the potential to learn about how such an issue is handled within society and one can learn about the interplay of science with ecology, economics, politics, cultural beliefs and values" (Marks et al. 2014, p. 287).

Classical *Bildung* (von Humboldt) already had a critical dimension because of its relationship to the critical philosophy by Immanuel Kant. However, in practice the critical dimension has not been particularly prominent in all the *Bildung*-versions. Especially the Anglo-American liberal education-tradition has traditionally had a relatively uncritical approach to the classical Greek and Latin culture (Gustavsson 2014b). However, through, for example, the work of Nussbaum in America and even more Klafki and also scholars of *Critical Theory* in Germany this has changed. For some of the latter a critical perspective "…is realised by reflection, by activating critique as a moral-philosophical-existential-political alternative" (Gur–ze'ev 2002, p. 404). An important concept in critical theory is *emancipation*, which can be defined as "eliminating oppression and creating conditions for effective agency" (Zembylas 2006, p. 665). Below this is called a 'critical-emancipatory approach'.

The concept of *Bildung* has itself been criticized and problematized, mainly by postmodern theorists (Løvlie et al. 2003, reviewed in Hansen 2008). Recently, Schaffar and Uljens (2015) identified the following two central points of criticism: (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, whereby *Bildung* is reachable only for the elite and that it is thus serving and supporting existing cultural structures of power. However, Biesta (2002b) claims that *Bildung* still works as a critical concept in a postmodern world. But he has argued against "certain versions of the critical theory of *Bildung* and critical pedagogy" with the ambition "to 'read' power behind knowledge" (Biesta 2002b, p. 388). Instead, he referred to Latour's networks, in which knowledge and power are not separable. More recently, he discussed, based on writings by Freire, Foucault and Rancière, a dialogical approach to emancipation. In such an approach, doing things differently to show alternatives, are emphasized (Biesta 2012). To sum up we – just like Klafki, Kemp, Biesta and others (e.g. Kemp 2005) – claim that criticisms of the concept can be counteracted by arguing for a contemporary and complex version of *Bildung* (we call it critical-reflexive *Bildung*) and by emphasizing that *Bildung* is something for all citizens in our complex and globalized society. In the next section we discuss different meanings of the term 'critical' in an educational context.

4.4 *Bildung*-Oriented Education for Critical Thinking and Responsible Actions

The word critical is used in a variety of forms in curricula, for example as critical skills and critical thinking. Johnson and Morris (2010) have discussed how critical citizenship can be understood as the intersection between critical thinking and

critical pedagogy. For them, critical thinking is associated to abstract and technical skills and has an individualistic focus, whereas critical pedagogy has a collective focus and is driven by a concern for socio-ecojustice.

The core explanation of critical thinking (CT) is that it is something cognitive, that is, for example logical reasoning. However, the term can also be understood in a broader sense. It has also to do with awareness of the own way of learning (metacognition) and philosophical-ideological awareness. Learning connected to the latter can be called epistemic and transformative learning (Sterling 2011). The core understanding of CT, that is cognitive and intellectual thinking, has been called the first wave, whereas a broader understanding of the term is called the second wave of CT (Walters 1994). Bohlin (2009, p. 190) has described it in the following way: "good thinking requires logical skills but is not exclusively defined by them; creative imagination, empathy, and self-reflective awareness of one's own presuppositions are equally important". Similarly, Hasslöf and Malmberg (2015) recently showed that critical thinking can have various meaning depending on different epistemological views; sometimes it is based on the educational aims of qualification and socialization, and sometimes subjectification. Especially the latter is related to the concept of *Bildung* (Biesta 2012; Schneider 2012; Straume 2015).

With reference to the moral philosopher Richard Hare (1919–2002), Vieira et al. (2011) described CT as one of the central ideas behind education and suggest that it forms the social basis for the achievement of equal rights and freedom within democratic societies. For Hare there are three justifications of CT: intellectual, pragmatic, and ethical. However, we think that the term *critical approach* better mirrors this broader meaning of CT and is more appropriate to be used in relation to *Bildung*. According to Gustavsson (2014b), a critical approach encompasses both to think and act critically, and to do so both in theory as well as in practice.

Another related term, already suggested above, is *critical praxis*. Critical praxis is an important goal of critical pedagogy. Critical approaches in education have followed two main lines: In Germany a critical-emancipatory approach was based on the early work of Habermas, and in North America a critical theory of education was developed based on writings by, e.g., Dewey and Freire (Biesta 2012). Freire's educational approach "…is essentially a humanistic pedagogy concerned with the real context of human conditions, particularly focused on the oppressive context" (Santos 2009, p. 364). The focus of critical pedagogy is the relationship between knowledge and power and its agenda is transformation of knowledge (e.g. curriculum) and pedagogy (e.g., teaching) (Cho 2010). With reference to Dewey and Freire, Reis (2014) claims that critical pedagogy suggests education as a democratizing force and in the same time being a catalyst for individual development and social transformation. More in detail, Shor (1992) in her book *Empowering Education* defined critical pedagogy as: "Habits of thought, reading, writing, and speaking which go beneath surface meaning, first impressions, dominant myths, official pronouncements, traditional clichés, received wisdom, and mere opinions, to understand the deep meaning, root causes, social context, ideology, and personal consequences of any action, event, object, process, organization, experience, text, subject matter, policy, mass media, or discourse" (p. 129). In other words, at the

heart of critical pedagogy are the ideas of education for awareness, praxis and dialogue (Bader and Laberge 2014). It can be seen as the educational implication of *Bildung* (in its critical-reflexive version). The goal of *Bildung*-oriented education is transformation of both the subjects/individuals/citizens and the global society towards sustainability.

Transformative learning can be understood as a deep shift in perspective focusing on making the habits of mind in the young generation more open, more permeable and better justified (Cranton 2011). This is expected to occur when people start to critically reflect on their instrumental and communicative knowledge. Houwer (2014) supports this view by arguing that crises are opportunities for transformative practices. Transformative learning is also about addressing the critical dimensions of certain contexts (Sterling 2011) and focusing the transformation of attitudes, behaviors, values, beliefs, and corresponding action (Carter et al. 2014). According to Bohlin (2008, p. 8) transformative learning, although only seldom explicitly associated with the idea of *Bildung*, "indicates ways to implement the ideal of moral *Bildung* in educational practice" (see also Bohlin 2013). For us a core idea of critical-reflexive *Bildung* is to critically identify cultural presuppositions and to support alternative ways of thinking and acting in dialogue with the surrounding world.

4.5 Towards *Bildung*-Oriented Science Education

As we have pointed out previously, except for scientific concepts and models which are in focus in traditional science education, scientific processes and societal contexts need to be also emphasised in humanized, socio-critical and *Bildung*-oriented science education (Marks and Eilks 2009; Sjöström 2013a; Sjöström and Talanquer 2014). This means that without including ethical and socio-political perspectives into STEM teaching, science learning will miss essential aspects that contribute making it relevant education (Hofstein et al. 2011; Stuckey et al., 2013). This necessarily includes a focus on understanding uncertainties and balancing benefits and risks (Sjöström 2013a). It also is in line with the thinking of Albe (2013), who claims that we need to rethink our culture and the way science education is being thought. She argues for a shift from the almost exclusive focus on subject matter content to socio-educational aims and preparation for socio-political action. We agree that science education should go in a socio-scientific direction, but just like Klafki we also think that relevant subject matter content is important.

Santos (2009) discussed the implications of critical pedagogy (a Freirean perspective) on science education and teaching. It is a radical view of scientific literacy, where not only socio-political perspectives are incorporated; the focus is on the political aim of transforming society to overcome oppressive conditions. Freirean-oriented science education can, according to Santos, be characterized by the following three aspects: (1) discussions of socially relevant themes by SSIs, (2) establishment of a dialogical process in the classroom, and (3) engagement of students in socio-political actions. He writes: "Freirean science education ought to take

SSI as the goal of attaching social meaning to science content, and of helping students understand the oppressive context of modern society" (p. 374). Science teaching "should be developed with grounds on students' cultural context through socially relevant themes that incorporate issues of oppressive context in society, and that ought to be developed through a dialogical process in classrooms, engage students in sociopolitical action and thus make it possible to look forward to bringing equity and social justice into our world" (p. 377). More recently, Bader and Laberge (2014) also claimed that the general principles of critical pedagogy should be applied in science education. For them critical pedagogy is focusing on reflexivity on any ideologies that orientate our worldviews. They emphasize the importance of making school science meaningful for the students and claim that critical perspectives are still too often neglected in school science.

Hart (2012), who writes about what he calls a post-critical pedagogy for science education, focuses on the need to change the discourses in science teaching, rather than changing the students. He claims that traditional science education is based on a rationalist-objectivist foundation and that "serious consideration of how people learn implies changes […] to one that engages a range of personal sociocultural and political issues within a frame of multiple ways of knowing" (p. 104). In a way the tension can be understood as a conflict between modernism (including scientism) and postmodernism in science education (Blades 2008). It also mirrors a tension between views in traditional science education versus common views in the area of contemporary environmental education (Dillon 2014). The latter focusses much more on interactive relational production of knowledge. Similarly, Colucci-Gray and Camino (2014) write about 'science of relationships' and 'epistemic and reflexive knowledge'. On the other hand, contemporary science education (Bencze and Carter 2011), and actually also the field Education for Sustainable Development (ESD) (Jickling and Wals 2008), is sometimes framed in a neoliberal ideology. The discourse of ESD is partially focused on ecological modernisation (Sjöström et al. 2016). It is based on "assumptions about progress, a human-centered world, and individualism" (Bowers 2002, p. 28) and results in overvaluing the chances of technology compared to ethical and cultural values and politics (Bader and Laberge 2014).

Education for Sustainability (EfS) is a more critical alternative to a narrow focussed ESD (Simonneaux and Simonneaux 2012; Birdsall 2013; Thomas 2009). According to Albe (2013) it requires the individual to take the political dimension of any environmental issue and their intrinsic power relationships into consideration. The aim is to empower the individual for acting responsibly in terms of sustainability, which was also identified by Stuckey et al. (2013) as an essential justification in their model of relevant science education. Other related and critically oriented alternatives are called, e.g., ecojustice education (Bowers 2002; Mueller 2009), ecocritical pedagogy (Garrard 2010), and activist environmental education (Burns and Norris 2012). All these call for a much higher degree of transformation than it is normally the case in many ESD examples (Burmeister et al. 2012). In an abstract for a keynote speech at the 8th World Environmental Education Congress in Gothenburg, Sweden in the summer 2015 professor Arjen Wals wrote:" Perhaps

a key lesson from the UN DESD [the United Nations World Decade of Education for Sustainable Development] that ended in 2014 is that we have come to realise that sustainability as such is not a destiny or a way of behaving that can be transferred or trained but rather represents our capacity for critical thinking, reflexivity and transformation."

To increase sustainability perspectives in science teaching, Littledyke (2008) argues for integrating cognitive and affective domains. For example, it was suggested to include politicisation of science education to address socio-scientific and environmental issues. In an illustrative figure he describes the difference between modern/traditional science and postmodern science, and also its consequences for pedagogy. According to him modern/traditional science is characterised by a stereotypical separation between cognitive and affective domains and it can be described with labels such as objectivism, reductionism-mechanistic and value-free. The corresponding pedagogy is described by him with labels such as transmission, non-contextual and facts-based. Instead he suggests constructive postmodern science that is characterised by integration between cognitive and affective domains, critically informed views of issues, systems thinking and uncertainty. The corresponding pedagogy Littledyke describes with labels such as active learning, interdisciplinary approach and real-life contexts. In line with this, Colucci-Gray et al. (2013) suggest that involvement of the learners is needed at a personal and emotional level to allow for finding ethical positions.

From a postmodern perspective on risks, the society cannot leave it to the experts to deal with them. According to Christensen (2009) postmodern risk-oriented science education has two challenges: (1) to work more with knowledge uncertainty, and (2) to work with both sides of science – the good and the bad, i.e. science as Janus-faced. Examples of teaching models, which takes these challenges in consideration, are the so called STEPWISE framework for activist science and technology education by Bencze and Carter (2011), a model of socio-scientific sustainability reasoning (S^3R) by Morin et al. (2014), and a framework for socio-critical and problem-oriented science teaching by Marks and Eilks (2009; see also e.g., Marks et al. 2014). In the latter Eilks and co-workers have conceptualised principles of socio-critical science teaching and corresponding evidence-based lesson plans. These start with current, authentic and controversial problems being debated in public, e.g., debates about alternative fuels, climate change, diets, or risk chemicals in consumer products (Eilks et al. 2013). All the lessons include learning of scientific content knowledge and experiments. However, by mimicking authentic non-scientific practices of information handling in society, all the lesson plans focus an understanding how science is used (and sometimes misused) by scientists and non-scientists in society. Examples included mimicking the work of e.g., politicians, representatives of pressure groups, journalists, consumer testers, or advertising experts. This approach was recently connected also to a further educational justification for critical science education. The suggested framework (see Fig. 4.1) is based on the socio-philosophical works of the Jewish-Polish philosopher Ludwik Fleck (1896–1961) (Stuckey et al. 2015).

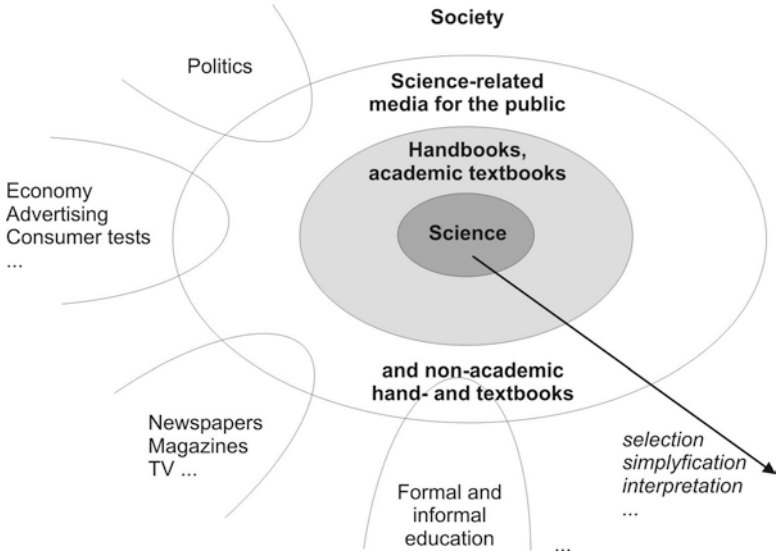

Fig. 4.1 A model for critically reflecting the science-to-society link (by Stuckey et al. 2015, based on Fleck 1935, and Bauer 2009)

The educational model based on Fleck justify reflective and critical learning about how information from the core domain of science is transferred into society, e.g., its presentation in the news media or its use in political debate. According to Stuckey et al. (2015) it is essential for understanding the often indirect and limited role science knowledge plays in societal decision making (see also Marks et al. 2014). The educational model, based on Fleck (1935) and Bauer (2009), illustrates how the core of real science endeavor is encircled by different media domains. It starts with journal and handbook science via scientific information for public understanding towards non-scientific practices of information use in society. With any further step away from the core of science, scientific facts or theories are purposely selected and presented; information is left out, intentionally or unintentionally biased, or used in suggestive ways. The model suggests that it is not only the understanding of science that allows for critically dealing with science-related media in everyday life. It is also necessary to understand the mechanism how science is transferred into and used within society, and at the same time selected, simplified and interpreted. It also suggests understanding and reflection about the skills and potential interests of all the persons involved in the information transfer processes.

4.6 Better Understanding the Different Visions of Scientific Literacy

In the beginning of this chapter we introduced a *Vision III* of scientific literacy (SL) that complements Roberts' (2007, 2011) Vision I, which focuses on scientific content and scientific processes for later application, and Vision II, which aims at understanding the usefulness of scientific knowledge in life and society. Vision III is about scientific "knowing-in-action" (Aikenhead 2007) and has also been called "critical scientific literacy" (Hodson 2009, 2011). It implies a politicised science education aiming at dialogical emancipation and socio-ecojustice, and emphasizes transdisciplinarity, philosophical values and praxis-oriented global citizenship.

To get a better understanding of this praxis-oriented vision of SL we have discussed the term 'critical' in relation to education (for example critical thinking and critical pedagogy) and also how it can be understood based on the Central/Northern European educational tradition called *Bildung*, which we above have described in detail. As we showed, it is a multifaceted tradition that has evolved over more than 200 years and we have paid most attention to the most complex version, which we call critical-reflexive *Bildung*. We have also discussed its educational implications and how it relates to other praxis-oriented educational paradigms such as Education for Sustainability and transformative learning.

The goal with this part of the chapter is to give an even better illustration of the different SL-visions, by comparing them in different ways. It is always difficult to categorize, but to describe it in a simplified way Vison I focuses on disciplinary scientific content knowledge, Vision II on usefulness of scientific knowledge in everyday life, and Vision III on critical praxis in relation to science and technology in society.

The tension between Vision I and II is already well described in the literature (e.g., Roberts 2007, 2011; Roberts and Bybee 2014; Wickman et al. 2012). Zoller (2012) makes a similar subdivision between something that can be called a 'traditional approach' versus an 'alternative approach'. Zoller's alternative approach is somewhere in between what we here call Vision II and Vision III. He recommends shifts from growth at any cost to sustainable development, from corrective responses to preventive actions, from disciplinarity to problem-solving orientation, from reductionist thinking to system thinking, and from lower-order cognitive skills to higher-order cognitive skills.

Wickman et al. (2012, p. 42) describe the rationalistic orientation and content focused character of Vision I in the following way: "we need to stay away from the non-cognitive" and "scientific reasoning are the cures for the irrational". To them, Vision I-thinking is characterized with a positivistic culture, scientific findings are often presented as objectively true or false, and values are seen as subjective. Smith and Gunstone (2009, p. 14) connect Vision I to a neoliberal ideology and write: "Science education's attempt to see educated citizens as 'mini-scientists' is both futile and self-defeating. […] The dualistic thinking that separates the education of future scientist from that of future citizens itself draws from the dualism that sees

Table 4.1 Connections between the three visions of scientific literacy, different knowledge types/ideals, aims with scientific research and emphasis in science education

Vision	Knowledge types/ideals	Aim with scientific research (Sjöström 2013b)	Emphasis in science education
I: Pipe-line science	*Theoria/episteme*	Development of scientific understanding (mode 1)	Epistemological
	Intellectual		
	Disciplinary rationality		
II: Science for all	*Techne*	Growth and wealth, including sustainable development (mode 2)	Everyday life and usefulness
	Pragmatic		
	Technical rationality		
III: Science for transformation	*Praxis/phronesis*	Democracy and justice; critical sustainability (mode 3)	Ethics and transformation
	Emancipatory		
	Critical rationality		

science as separated from society". Roberts (2011) connects four (of the seven) curriculum emphasizes (solid foundation; structure of science; correct explanations; scientific skill development) to Vision I and the other three (self as explainer; everyday coping; science, technology, and decisions) to Vision II. According to Wickman et al. (2012) Vision II can be understood as learning about the various contexts in which students in their daily life are faced with problems involving science. However, there can be different complexity of contextualized science education (e.g., Sjöström and Talanquer 2014). Both Vision II and Vision III emphasize relevance, but if Vision II focuses on everyday-life relevance, Vision III focuses more on problematized relevance for critical citizenship and sustainability.

Lundqvist et al. (2013) have discussed Vision I and II based on the three types of knowledge identified by Aristotle: theoria, techne and praxis/phronesis (see also Roberts and Bybee 2014). They subdivided Vision II into two types: *Vision IIa* is based on the assumption that applying knowledge (Techne) is something different than only knowing (Vision I is, according to Lundquist et al. only focusing on Theoria, as a way of thinking and arguing). In *Vision IIb* (with similarities to what we here have called Vision III), Vision IIa is complemented with an emphasis of ethical and political values (Praxis/Phronesis).

Here we further highlight the tension between Vision II and III, with the risk of categorizing too hard. For example, the tension can be understood by help of terms such as: modernism (Vision II) and postmodernism (Vision III); neoliberalism (Vision II) and ideological awareness (Vision III); sustainable development (Vison II) and critical sustainability (Vision III); and cognition/metacognition (Vision II) and epistemic and transformative learning (Vision III). In Table 4.1 we further illustrate the differences between the three visions by connecting them to different knowledge types/ideals (for example Aristotle's three types of knowledge) and different emphasis in science education. However, regarding knowledge types we

must emphasize that critical-reflexive *Bildung* (Vision III) does not only focus on phronesis, but on phronesis in addition to episteme and techne.

Table 4.1 also includes a connection to different aims with scientific research. These have been described with different modes (Sjöström 2013b), which correspond relatively well with the visons of SL (see also Wickman et al. 2012). Mode 1 emphasizes fundamental disciplinary knowledge, and Mode 2 collaboration and instrumental usefulness (Gibbons et al. 1994), or as Wickman et al. (2012, p. 41) writes: "Mode 1 is academic, scientist-initiated and discipline-based production of knowledge, whereas Mode 2 is context-driven research in the sense that it is more focused on solving specific problems, and invokes interdisciplinary knowledge as needed". Fuller (2002) has suggested a complementary Mode 3 which pays attention to what is useful for the public and the civil society. We think that this mode corresponds to Vision III of scientific literacy.

The three modes and visions are also in line with an analysis of traditional and alternative curriculum orientations in the historical development of science education curricula as suggested by Eilks et al. (2013). Traditional curricular approaches from the 1950s to the 1970s were described as mainly focusing the structure of the discipline, the history of science and the mimicking of the work of scientists. Curricula following a context-based science education paradigm emerging in the 1980s and 1990s were characterized as still focusing the learning of science concepts and processes as their main goal. However, they do so by embedding the learning of science in everyday-life, societal or technological contexts for promoting meaningfulness and applicability of the learned subject matter. The latter was put into contrast with SSI-based and EfS-driven curricula, which were suggested not only aiming on content learning via context, but from the beginning aiming at general educational skill development and transformative education via making authentic and controversial issues from everyday life and society the drivers for science education. Which approach is chosen needs to be decided by the objectives of the teaching and its target group (Stuckey et al. 2013).

Different actors in society seem to have differences in their views and interests on the different visions respective modes of science learning (Aikenhead 2006). The state and the industry seem to prefer – from somewhat different perspectives – more of Mode 2 science, whereas many academic researchers would like to go back to more of Mode 1 science (Sjöström 2013b). Mode 3 science, on the other hand, focuses on responsible research and innovations (Sjöström 2013b). The corresponding Vision III of SL focuses on developing critical citizenship.

As already mentioned above, from a simplified point of view SSI-education can be seen as typical for Vision III-driven science education. In a complex form this is true, but there are also many less complex forms of SSI-teaching, normally even more in practice than in theory. Recently, Simonneaux (2014a) discussed different curriculum orientations of SSI-education using continuums from 'cold' (mainly emphasizing, e.g., monodisciplinarity, scientific learning, and epistemic values) to 'hot' (also emphasizing transdisciplinarity, political citizenship, and philosophical values): "At the 'cold end' […] knowledge mobilized in the classroom is single-disciplinary science. At the 'hot end', it is discussed in interdisciplinary

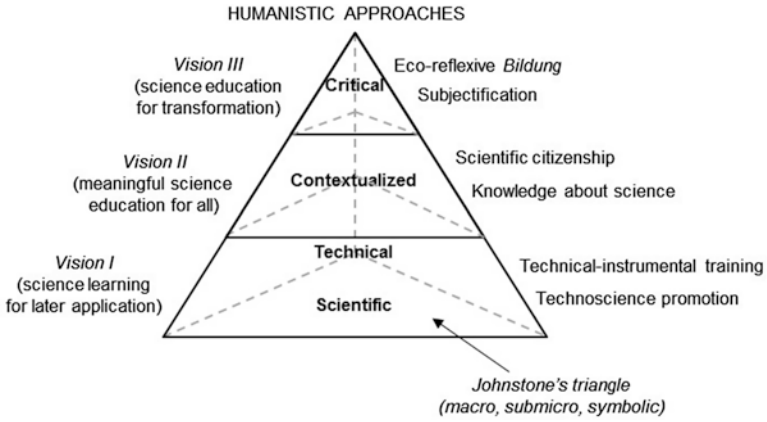

Fig. 4.2 Three levels of humanized science education

sessions in science and humanities" (Simonneaux 2014b, p. 106). In the middle of Simmonneaux's (2014a, b) model we find for example knowledge about science, critical thinking, social values, and scientific citizenship; STSE-contextualization is emphasized, but focus is on cognition and evidence-based argumentation. This is problematized at the hot end, which also contains e.g., ethical reflection.

Wickman et al. (2012, p. 17) writes: "to make meaningful actions possible, both knowledge and values are necessary […] it is crucial that not only cognitive dimensions but also values more generally are included." The continuum goes from 'techno-scientific rationality' – based on a belief that techno-scientific progress will resolve current problems – to a 'critical rationality', involving reflexivity towards the techno-sciences (Simonneaux 2014b, p. 107). Similarly, Pedretti and Nazir (2011) have discussed different orientations of STSE education – from application-oriented via socio-cultural-oriented to socio-ecojustice-oriented. Comparing this with the three visions of SL we would claim that Vision I is at the cold end, Vision II in the middle, and Vision III at the hot end of Simonneaux's continuum.

Another, and final, way to illustrate the increasing complexity from Vision I to Vision III is to use a tetrahedron model for *Bildung*-oriented chemistry education suggested in Sjöström (2013a) and Sjöström and Talanquer (2014). The top of the tetrahedron symbolises the human element and can be subdivided into three levels. These three levels are called: (1) applied chemistry, (2) socio-chemistry, and (3) critical-reflexive chemistry (Sjöström and Talanquer 2014). Figure 4.2 illustrates, based on the model, different orientations in humanized science education. The triangular bottom and level 1 corresponds to Vision I, and level 2 to Vision II. It is suggested that a politicised and eco-reflexive (Sjöström et al. 2016) science education aiming at critical-reflexive *Bildung,* subjectification and transformation, i.e., Vision III-driven science education, should be placed in the top of the tetrahedron.

4.7 Concluding Remarks

This chapter discusses the Central/Northern European educational theory of *Bildung* with respect to different visions of scientific literacy and science education. *Bildung* has a tradition of more than 200 years and forms the central socio-cultural theory of education in German speaking countries and Scandinavia (Westbury et al. 2000). Because of this history and the large influence of *Bildung* on societies in many Central/Northern European countries, *Bildung* needs to be considered as an inseparable part of culture in the corresponding countries, e.g. Germany and Sweden. Unfortunately, the unique concept of *Bildung* was largely neglected in the international discussion about goals and pedagogies in science education until quite recently (e.g., Sjöström 2013a).

Bildung is more a vision of development of a person in interaction with the surrounding society and the world, than it is a theory of the curriculum or a pedagogy. However, this vision has many implications for both fields. Since *Bildung* suggests that any kind of education should focus making the young generation capable for a self-determined life in society, for being able to participate and solve problems in it, as well as being empathic and to show solidarity, it suggests the development of certain skills (Hofstein et al. 2011). Similarly, Crippen and Antonenko (2018) in Chap. 5 of this volume discuss the need for science education to focus more on problem-solving skills by the individual in a societal context. We also agree with Avargil et al. (2018), who in Chap. 3 of this volume argue metacognitive skills are important for scientific literacy. However, we add that learning must be complemented with not only metacognition, but also with epistemic and transformative learning components (Sterling 2011).

Since *Bildung*, in the means of *Allgemeinbildung*, focuses on all learners and on all domains of personality development, science education has to contribute to corresponding educational skill development and to broaden its focus to all learners (also to those that will not embark in a later career in STEM professions). Relevant science education needs to recognize more thoroughly its societal dimension (Stuckey et al. 2013). It has to focus not only on science as an academic and industrial endeavor, but also to help understand science as a sociological construct embedded within society (Stuckey et al. 2015) and to learn about its relations to technology, culture and values as discussed from a different perspective by Waight and Abd-El-Khalick in Chap. 7 of this book. It needs to accept its responsibility for promoting critical scientific and technological literacy by promoting societal-oriented problem-solving and participation skills in the means of *Bildung*/Vision III, as outlined here.

This chapter suggests a stronger recommendation of concepts such as Education for Sustainability, transformative learning and complex SSI-based STEM education to focus on both the cognitive and the affective domains in the learner, when it comes to deal with information and issues stemming from science and technology. Many cases suggest the motivating character of SSI-based science education and in the meantime provide indication of potential for the development of *Bildung*/Vision

III-oriented skills (Sadler 2011; Marks and Eilks 2009; Marks et al. 2014). With a growing complex world, which Elmose and Roth (2005) describe as the risk society, such skills are needed to allow the younger generation to become critical-responsible citizens.

While learning about *Bildung* is an essential point in teacher education in all pre-service teacher education programs in the German-speaking and Scandinavian countries, this is not the case in the international literature, and it may even be unknown in teacher education in most countries. We suggest that teacher education also in these countries can benefit from a discussion of and reflection on *Bildung*. It might be discussed in comparison to international traditions and theories of the curriculum, education and teaching in science and technology education. Considering the basic philosophy of *Bildung* in science education might help teaching knowledge and skills in the young generation to transform our world and societies in a sustainable way. The goal of *Bildung*-oriented education is transformation of both the individuals/citizens/subjects and the society towards sustainability and development.

We conclude the chapter with the following three summarizing bullets:

- *Bildung,* in a critical understanding, is "the central critical concept of modern pedagogy" (Wimmer 2003, p. 185). *Bildung* has both educational and political dimensions. For over 200 years now, it became an essential and influential part of middle and northern European culture and educational policy. It should find better recognition and broader reception also in other countries and the international literature.
- Connecting *Bildung* with reflecting the goals of science education suggests that there should be a third vison of scientific literacy beyond the two visions described by Roberts (2007). *Bildung*-oriented STEM education needs to focus at a critical vision of scientific literacy, action competence, and critical praxis. This third vision (Vision III) of scientific literacy, inspired by a critical-reflexive understanding of *Bildung,* goes beyond contextualization of science learning. It describes a politicised vision of science education aiming at dialogical emancipation, critical global citizenship, and socio-ecojustice. This has consequences for the science curriculum that needs to incorporate more thoroughly a societal perspective and needs to incorporate stronger socio-scientific issues based science education (hot-type) and corresponding pedagogies.
- Vision III of scientific literacy asks for both reconsidering the contents and contexts of science education. Controversial, relevant and authentic socio-scientific issues, e.g., from the sustainability debate, shall become the drivers for the curriculum. Corresponding research, curriculum development, and teacher continuous professional development needs to be intensified.

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