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ARTICLE

Traces of *Bildung* in Upper Secondary Science Education: A Critical Investigation of Chemistry Teachers' Orientation Towards Promoting *Bildung* in Chemistry Education

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Abstract
There is a need of a component in science education that can orient students to the complexity characterising the natural sciences position in relation to a globalised risk society and the Anthropocene. Recently, the implications of the German philosophical and educational construct *Bildung* have been discussed in this regard. In this paper, we investigate in what aspect an orientation towards promoting *Bildung* manifests in Swedish upper secondary school chemistry teachers' visions and views for their teaching. In view of the reported impact of neoliberal policy in narrowing the scope of education, with such narrowing possibly excluding dimensions of philosophical-ethical reflection in science teaching, we also investigate in what aspect economic goals associated with neoliberalism might hinder a *Bildung* orientation in the vision and views of the five chemistry teachers that were interviewed. Results revealed "*Bildung*-related elements" to be present in the chemistry teaching visions of all the teachers, however without strong *Bildung* orientation. Significantly, four of the five teachers reported contextual factors consistent with the impact of neoliberal policy in education as marginalising their work to realise *Bildung*-related elements. In addition, factors outside of teachers' awareness were also found to marginalise *Bildung*. Common for all five teachers were neoliberal values at the level of teachers' implicit beliefs, with our analysis pointing to the possibility that teachers view *Bildung*-related elements in their chemistry teaching as commodifiable entities. We argue that these implicit beliefs disempower the teachers in relation to a teaching praxis that seeks to guide students towards their own *Bildung*.

1 Introduction

1.1 The Natural Sciences, Science Education, Risk Society, and the Anthropocene

The application of knowledge from the natural sciences plays a central role in the industrial, techno-scientific, and economic development of today's modern societies (see for

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example Rodriguez, 2014; Pleasants et al., 2019). The disciplines of the natural sciences therefore should be viewed as being intimately tied to social, economic, political, environmental, and ethical dimensions (e.g. Sjöström et al., 2016; Stables, 2017; Sjöström & Eilks, 2018; Falloon et al., 2020; Pleasants, 2020; Valladares, 2021). Of central significance in this regard is the fact that, when applied, not only does knowledge from the natural sciences contribute to the creation of products with high societal value; it also contributes to local and global environmental impact and risk (Smith & Watson, 2019). The natural sciences can be viewed therefore as being immutably connected with the idea of a globalised risk society (e.g. Beck, 1992; Sjöström et al., 2016; Stuckey et al., 2013) and the Anthropocene epoch (e.g. Mahaffy, 2014; Blatti et al., 2019; Mahaffy et al., 2019; Zowada et al., 2019a, 2019b). Helpful to understanding the natural science's position in relation to risk society and the Anthropocene epoch is the term *complexity*. Sjöström et al. (2016) for example use the term when referring to the unpredictable consequences that can arise through the manufacture and use of techno-scientific innovations. The term is also used to highlight the existence of a plurality of perspectives in relation to techno-scientific applications that are disseminated into the public forum by stakeholders with differing interests (Sjöström & Stenborg, 2014). Additionally, Levinson (2010) uses the term when describing the epistemological, technical, and multidisciplinary barriers that stand in the way of student's being able to be actively take a stance in relation to society's manufacture and use of techno-scientific applications.

The entanglement of neoliberal values with the natural sciences and science education. Of significance in regard of the complexity characterising the natural sciences in relation to a globalised risk society and the Anthropocene epoch is an emerging view of neoliberal values[1] as entangled with the natural sciences and science education (e.g. Bencze & Carter, 2011; Tobin, 2011; Bencze et al., 2014; Carter, 2014; Bazzul, 2016; Hayes, 2016; Carter, 2020; El Halwany et al., 2021; Bazzul, 2023). According to Bencze and Carter (2011), school science often functions in the service of such values, in part to create scientists and engineers who employ science with a view to producing techno-scientific applications and in part to create consumers who place their belief in the techno-scientific products that scientists and engineers produce. Of considerable importance in relation this idea is Stiegler's (2007) view of science as "no longer that in which industry invests, but what is financed by industry to open new possibilities of investments and profits" (p. 32).

Science education in the Anthropocene epoch. In light of economic neoliberal values being seen as entangled with the natural sciences, and hence globalised risk society and the Anthropocene, a science teaching that is politically neutral would seem something that is neither possible nor desirable (Hodson, 2003). Indeed, for citizens and future science professionals whose lives are impacted by the natural sciences as well as techno-scientific innovations that depend on the application of knowledge in the science disciplines, it seems evident that there is a need of a component in science education that can orient them to the

[1] Neoliberalism is a competition-oriented economic system that builds upon an idea of social prosperity as facilitated through the "fostering of individual freedoms and encouraging entrepreneurship within a framework of strong private property rights, free markets, and free trade" (Tobin, 2011, s128). Significantly, a key activity of the state in this regard is the creation of national and global free markets (Harvey, 2005). In territories where neoliberalism has proliferated, a reshaping of private and public sectors (as free markets) has taken place (ibid). With regard to the natural sciences and (science) education, values associated with neoliberal ideology—competition, enterprise, accountability, efficiency, productivity, and consumer choice—are seen as having become commonplace (Bencze & Carter, 2011; Tobin, 2011; Bencze et al., 2014; Carter, 2014; Bazzul, 2016; Hayes, 2016; Carter, 2020; El Halwany et al., 2021; Bazzul, 2023).

complexity that characterises the science discipline's position in relation to a globalised risk society and the Anthropocene epoch (see for example Ariza et al., 2021; Wallace et al., 2022; Georgiou & Kyza, 2023), as well as to neoliberalism's role.

1.2 *Bildung* as a Central Concept for Science Education in the Anthropocene Epoch

Recently, there has been a growing discussion in relation to the implications of the German philosophical and educational construct *Bildung* on science education (see for example Sjöström et al., 2017), including chemistry education (e.g. Sjöström, 2013; Sjöström et al., 2020; Yavuzkaya et al., 2022). According to Sjöström and Eilks (2018), a *Bildung*-oriented science education "goes beyond many understandings of scientific literacy in the literature" (p. 66). An important distinction in this regard is the inclusion of more ethical and critical perspectives in science teaching regarding science and its role in society (Sjöström, 2013; Sjöström et al., 2016).

As a philosophical and educational tradition, *Bildung* dates back to the late eighteenth century (e.g. Yavuzkaya et al., 2022). Directly translated into English *Bildung* means *becoming in the image of*, the term—in its classical understanding—pointing to an idea of the person as cultivating or improving themselves in relation to an ideal image of something for humankind to become (ibid). Significantly, the ideal image that *Bildung* is seen as representing is viewed as always being bound to the culture and society in which the *Bildung* subject is situated (Horlacher, 2016). *Bildung* thus may be understood differently depending upon the context *Bildung* is situated within (ibid). In view of this, *Bildung* has been criticised for not being a "thing" on its own (Biesta, 2002). However, ideas of *Bildung* as being related to integration/wholeness (as opposed to fragmentation), the cultivation or improvement of the self (as virtue), the binding or linking of the self to the world, self-determination, and the shaping of each subject's unique perspective, seem to have persisted since the late eighteenth century (see for example von Humboldt, 2000). For example, Wolfgang Klafki (2000a, 2000b), who played a prominent role in developing German education in the twentieth century, captures ideas of self-determination, learning as bound to a relation with the world, integration/development of the whole person—"head, heart, and hand" (p175)—,and moral self-cultivation in his definition of *Bildung*.

Recent publications concerning *Bildung* point to *Bildung* as being concerned with an inward self-examination (self-reflexivity) that enables a responding to key issues/problems associated with the *Bildung* subject's surrounding context (Buttigieg & Calleja, 2021; Kvamme, 2021; Ørbech Jensen, 2021; Riese & Hilt, 2021). Significantly, this process of self-examination is seen as taking place in a perspective of humans as relationally bound and indivisible from the world (Buttigieg & Calleja, 2021; Kvamme, 2021; Ørbech Jensen, 2021; Riese & Hilt, 2021; Rømer, 2021; Ryen & Jøsok, 2023; Waterman-Evans, 2022). In this view, the surrounding context and the *Bildung* subject are both seen as being fundamentally "a part" of *Bildung*. Learning and change taking place through *Bildung* therefore impact both the *Bildung* subject and their surrounding context (ibid). That is, *Bildung* involves subjects, through self-cultivation in relation to their surrounding context, coming to an ethico-sociopolitical agency as a part of their surrounding context (see for example Yavuzkaya et al., 2022). In a contemporary sense, this might mean a process of subjectification in which subjects, in coming to a critically reflexive stance, are capable of successfully responding to key issues/problems associated human impacts on the systems of the Earth (e.g. Buttigieg & Calleja, 2021; Kvamme, 2021; Ørbech Jensen, 2021; Riese & Hilt, 2021).

With a view to an education in the natural sciences that can orient students to the complexity characterising the different disciplines' relation to risk society and the Anthropocene, as well as to neoliberalism's role, we believe the *Bildung* construct to be theoretically well positioned. To provide additional theoretical support for this position, we provide here a brief theoretical deepening that draws from two complimentary perspectives on *Bildung*: *Bildung* seen as a counter-concept and a critical- or eco-reflexive *Bildung* construct for science education.

Bildung as counter-concept. The origins of the idea of *Bildung* as a counter-concept lie in the emergence of *Bildung* as a pedagogical construct in the modernising era of eighteenth century Germany (Alves, 2019). A reaction against a perceived fragmentation of knowledge and society (ibid), *Bildung* as a pedagogical construct, emerged in the face of developments in the sciences, new technologies, increased division of labour, and knowledge specialisation. *Bildung* thus became a pathway for people to reconnect to the idea of humanity and be integral or whole "in a world increasingly similar to a vast machine" (ibid., p. 5).

As a counter-concept therefore, *Bildung* embodies critical and resistant elements, the purpose of which are to illuminate factors that threaten to reduce or narrow human beings' perception and constitution of reality (Wimmer, 2003). Seen in a contemporary context, that is, of continued societal technologisation, education as an arena for the effectivised production of "human capital" (Adolfsson, 2013; Gillies, 2014; Sundberg & Wahlström, 2012), and private life as reduced to a worldview that narrows the subject's relating with the world to its utilisation as a commodity (Freudenberg, 2021; Heron, 2008; Kocka, 2016), the role of *Bildung* as a counter-concept could rightfully be viewed as critically important today. This is not least because of the association of *Bildung* with the idea of education as having a broader value, and not something that can be characterised in instrumental terms only (Schnack, 2008). Of particular importance in this sense is the idea of learning in *Bildung* as something that is intrinsically motivated (Nordenbo, 2002), and of the learner as self-actively coming into a dialogue with *the Other* (Gustavsson, 2014). Crucial in this regard is the idea of volition in relation to the subject making use of information acquired so as to give it structure and meaning and hence knowledge being an integral part of the subject's identity (Wimmer, 2003).

A critical- or eco-reflexive Bildung construct for science education. Sjöström and colleagues (e.g. Sjöström & Eilks, 2018; Sjöström et al., 2016, 2017) have drawn from the works of Hans-Georg Gadamer (1900–2002), Paul Ricoeur (1913–2005), and German educational philosopher Wolfgang Klafki (1927–2016) in developing a framework for a critical- and sustainability-oriented chemistry and science education. Posited as a metatheory for contemporary chemistry (and science) education, critical- or eco-reflexive *Bildung* includes ideas of critical reflexivity, emancipation, critical-democratic awareness, sociopolitical action, and eco-justice (ibid). As a framework, critical- or eco-reflexive *Bildung* suggests a chemistry (and science) teaching that orients student's in "a critical stance towards the modern risk society, an understanding of the complexity of life and society and their interactions, and a responsibility for individual and collective actions towards socio-ecojustice and global sustainability" (Sjöström et al., 2016, p. 336).

Sjöström and his colleagues have closely related critical- or eco-reflexive *Bildung* to a critical view of scientific literacy which they term Vision III (e.g. Sjöström & Eilks, 2018). In connection with this, Sjöström (2013) has previously described a three-level model for chemistry teaching embodying a "human element" which the author relates to Roberts' visions for scientific literacy. Representing an earlier framework, Sjöström relates the first two levels, "applied chemistry" and "socio-cultural context", to scientific literacy, with the

former—together with "pure chemistry"—being related to Vision I and the latter—contextualised chemistry—to Vision II (ibid). Crucially, the third level in this earlier framework, termed "critical-philosophical approach" and viewed as representing an eco-reflexive *Bildung*-oriented chemistry (and science) teaching, may be viewed as corresponding to a critical view of scientific literacy and thus Vision III (Sjöström & Eilks, 2018).

1.3 *Bildung* as the Core Concept of Nordic and Germanic Didaktik

In Sweden, as well as Germany and the other Nordic countries, *Bildung* is a central element of their educational tradition, which in disciplinary terms is termed didaktik (e.g. Carlgren, 2020; Deng, 2021). It is important to point out here that the term didaktik is understood differently to how the word "didactics" is understood in English-speaking countries (Krogh et al., 2021). In the Germanic didaktik tradition, the term didaktik refers to "a multifaceted view of planning and performing instruction [… concerning] the analytical process of transposing (and transforming) human knowledge (the cultural heritage) into knowledge for schooling that contributes to *Bildung*" (Duit, 2015, p. 325). Being the central discipline of the teaching profession in Germany and the Nordic countries, didaktik fundamentally concerns questions of *what* content is important to learn, *why* it should be taught, and *how?* (e.g. Wickman et al., 2012). In light of *Bildung* being seen as a central element of didaktik, we would anticipate *Bildung*, or dimensions that can be related to the idea of *Bildung*, to be an integral part of the work of natural science teachers teaching in the didaktik tradition.

1.4 Purpose of the Study and Research Questions

Considering the importance a *Bildung*-oriented teaching in the science subjects might have in relation to orienting students to ideas of complexity, globalised risk society, and the Anthropocene, we wanted to investigate in what aspect a *Bildung* orientation manifests in the "didaktik work" (including teachers "curriculum making") of natural science teachers who teach chemistry[2] in Sweden. That is, in what aspect an orientation towards promoting *Bildung* can be discerned in Swedish chemistry teachers' work with questions of *what* content is important to learn, *why* it should be taught, and *how*. In view of the centrality of the *Bildung* construct to the discipline of didaktik, evidence of an orientation towards promoting *Bildung* in chemistry teachers' didaktik work might be anticipated.

Crucially, *Bildung* is not alone in influencing the content and form of the Swedish school curriculum (Adolfsson, 2013). Gustavsson (2009) for example has discerned three dimensions arising from different historical sources of influence: economic goals associated with neoliberalism that serve Swedish and EU interests, goals that serve the interests of sustaining democracy in Sweden, and goals which can be described as *Bildung* goals. Of importance to this study, findings in Swedish education research suggest that economic goals associated with neoliberalism expressed within the Swedish curriculum dominate over or marginalise the curriculum's *Bildung* goals (e.g. Adolfsson, 2013; Lundgren, 2011; Sundberg & Wahlström, 2012). Fundamentally, such goals draw from competition as a central value of neoliberalism where education is seen as a critical pathway to generating competitive advantage in national and global markets (e.g. Hayes, 2016;

[2] Chemistry is a subject centrally linked with industrial, techno-scientific, and economic development and hence the idea of a globalised risk society and the Anthropocene (Yavuzkaya et al., 2022).

Sundberg & Wahlström, 2012; Tobin, 2011). Education becomes thus an arena for the effective production of human capital as a cost-, time- and results-effectivised production of people with the competencies needed for work (ibid). Crucial in this regard is that the performance of educational institutions is continually evaluated by the state in terms of their results and outcomes (ibid).

The idea thus that economic goals associated with neoliberalism marginalise the curriculum's *Bildung* goals raises questions as to what impact such goals might have on a potential *Bildung* orientation in Swedish chemistry teachers. We also wanted to investigate therefore whether economic goals associated with neoliberalism marginalise the possibility of a *Bildung* orientation in Swedish chemistry teachers' work with questions of *what* content is important to learn, *why* it should be taught, and *how*. In view of the importance of orienting students to ideas of complexity, globalised risk society and the Anthropocene, such an investigation seems highly pertinent.

Research question 1. In what aspect can an orientation towards promoting *Bildung* be discerned in Swedish chemistry teachers' work with questions of *what* content is important to learn, *why* it should be taught, and *how?*

Research question 2. In what aspect might economic goals associated with neoliberalism hinder an orientation towards promoting *Bildung* in Swedish chemistry teachers' work with questions of *what* content is important to learn, *why* it should be taught, and *how?*

2 Method

2.1 Research Design

Since there was no pre-existing knowledge base describing the aspect in which *Bildung* comes to expression in Swedish chemistry teachers' "didaktik work", this study necessarily has an exploratory dimension. However, given that our research questions are concerned with identifying qualities associated with categories identified prior to the study, that is, *Bildung* and economic goals associated with neoliberalism, this study has a distinctive deductive orientation. In view of an absence of available data in relation to the specific quality in which these dimensions might come to expression, however, we have chosen a qualitative approach. That a qualitative study should have deductive character is not uncommon however (Bhattacherjee, 2012).

2.2 Informed Consent and Confidentiality

Participants received written information regarding the study's area of interest prior to giving their consent. Participants were informed that the study was in "chemistry didaktik", that it was concerned with uncovering "chemistry teachers' thoughts and reflections in relation to their student's learning", and that the interview would give them the possibility "to deeply reflect over their didaktik praxis". On giving consent, participants were informed that their participation was voluntary and that they could end their involvement in the study at any time. No materials were produced that contained information pertaining to the identities of the participants. The participant's identities are known only to the corresponding author, and information pertaining to them has only been used for the purpose of this study.

2.3 Sampling Strategy

Using snowball sampling, five chemistry teachers—we call them here "John", "Jennifer", "Alex", "Anna", and "June"—working in upper secondary schools in Sweden were selected to take part in the study. A crucial sampling criterion for this study was that all teachers were licensed upper secondary school chemistry teachers with a minimum of 5–10 years teaching experience in teaching chemistry in Swedish schools. One of the teachers, Alex, in addition had a Swedish licentiate degree (which corresponds to a "half PhD") in chemistry. Since in Sweden it is common for upper secondary high school teachers to be qualified in the teaching of two subjects, participants were purposefully sampled to capture a range of different subject combinations with chemistry. Thus, John's other subject biology whilst Jennifer's other subject was mathematics. Alex and Anna's other subjects were in the humanities, and June's other subject was general science (*Naturkunskap* in Swedish), which in Swedish upper secondary education is a compulsory subject for students who would not otherwise study the natural sciences at this level.

2.4 Data Collection

The corresponding author employed a semi-structured interview to procure rich descriptions of each interviewee's view on the didaktik questions *what*, *why* and *how*. Crucially, in view of the study having deductive character, there was a stringent requirement that participants answered the interview questions in an honest and authentic manner. To avoid respondents attempting to behave in a "correct" way or seeking to be "good research participants" (see for example Shaughnessy et al., 2009), it was necessary therefore to avoid explicit use of the terms *Bildung* and "economic goals associated with neoliberalism" when sharing with participants information about the study. Participants were informed thus about the study in general terms (see 2.2). Also of importance in this regard was that the interview questions, whilst having the capacity to elicit responses that could enable the research questions to be answered, needed to be stated in a manner that also did not potentially threaten the study's internal validity.

Structured in two parts, the semi-structured interview sought to inquire into teachers' practice by drawing from the three core questions associated with Nordic and Germanic didaktik: *What* content is important to learn, *why* it should be taught, and *how?* (Wickman et al., 2012).

The interviews first part—teachers' vision for their teaching. The didaktik content (*What* content is important to learn?) and purpose (*Why* should it be taught?) questions may be viewed as being components of what one might call a teacher's vision for their teaching. Significantly, there are important links between questions of content and purpose and teachers' work to promote *Bildung* (see for example Klafki, 2000a, 2000b; Hopmann, 2000; Deng, 2021; Dolin et al., 2022). In view of these links, one would anticipate a *Bildung*-oriented teacher to fill their interview narrative with material consistent with *Bildung* when asked to describe their vision for their teaching in relation to questions of content and purpose.

In order that participants could be guided towards answering the didaktik content and purpose questions as distinct questions, the first part of the interview was divided into two separate questions. The first question asked participants to specify their vision for their teaching in terms of what content they wanted their students to learn. The second question asked participants to specify their vision for their teaching in terms of the value

they believed the knowledge their students learned would have for students themselves. The specific focus of this second question on the *value of learning* was informed by McGilchrist's (2009) divided brain hypothesis which can be viewed as delineating two divergent motives for learning in the world: (1) Learning with a view to grasping the world in a manner that can allow one to manipulate it and hence gain mastery and power over it and (2) learning "with a view to understanding the world as a whole and how to relate to it" (McGilchrist, 2021, p. 28). In our view, the first motive for learning is consistent with education seen as a vehicle for personal and national economic growth and competitive advantage (see for example Gillies, 2014), whereas the second is consistent with *Bildung*. By asking about the teachers' vision for their teaching in terms of the value they envisioned learning having for the students, we hoped to open to the creation of a distinction whereby content could be identified as being either consistent with *Bildung* or with economic goals associated with neoliberalism.

The interviews second part—teachers' descriptions of their work to realise their vision for their teaching. Following the first part of the interview, the second part of sought to garner information pertaining to the practical choices teachers made to realise their vision for their teaching. That is, how the teaching objectives they defined in the first part of the interview were achieved in practice (in their view); this question being consistent with the German and Scandinavian didaktik question "*How* should it be taught?" (Meyer, 2012).

Participants were interviewed individually in rooms suitable for the purpose at their respective schools. At the start of each of the two parts of the interview, participants were read a brief passage whose purpose was to prompt their thinking regarding the interview's themes: Teachers' vision for their teaching and teachers' practical choices for realising their vision for teaching. In the event of participants not understanding the interview questions as read by the interviewer, they were given the opportunity to read the questions themselves first before answering. Unscripted and spontaneous follow-up questions were used in addition to the scripted questions in the service of garnering rich narratives relevant to the research questions. Interviews lasted between 44 and 58 min. All interviews were recorded as digital audio files and transcribed verbatim.

2.5 Data Analysis

A within-case analysis was guided by Miles and Huberman's interactive model for qualitative data analysis (1994). Transcript texts were first condensed and displayed. Data was then analysed for content consistent with the idea of *Bildung* and the idea of neoliberal economic goals. Based on this, conclusions were drawn and then verified.

Teachers' answers to the didaktik "What" and "Why" questions were structured in the form of vision statements. So that statements were structured faithfully to transcript texts, the following process was followed: (i) each interview transcript (in Swedish) was read through several times until all passages related to teachers' vision for their teaching had been identified, (ii) vision statements were translated from Swedish and written in English by a native English speaker with more than 20 years' experience of speaking Swedish, (iii) vision statements were rigorously compared to original transcript texts in order to discern discrepancies, and (iv) vision statements were re-written until a point was reached in which all sense of discrepancy in meaning was absent.

Teachers' accounts of the choices they make to realise their vision for their teaching was structured as condensed versions of the original transcript texts. An equivalent level of rigour to that used when structuring teachers' visions for their teaching was applied so that all

sense of discrepancy in meaning between the condensed versions of teachers' accounts and the original interview transcripts was absent.

Following the initial structuring of the data each case was analysed for content consistent with the idea of *Bildung* (or a *Bildung*-oriented teaching) and economic goals associated with neoliberalism that are expressed within education. Because *Bildung* is a complex, multi-faceted construct, and drawing from Bhattacherjee's (2012) argument that qualitative research should avoid employing constructs that are too narrowly defined, we deemed it prudent to perform the analysis using more than a single theoretical perspective of the *Bildung* construct. Thus, in addition to a perspective concerning what is meant by economic goals associated with neoliberalism as expressed within education (Adolfsson, 2013; Heron, 2008; Sundberg & Wahlström, 2012), we have used four unique perspectives or views of what is meant by *Bildung* (or a *Bildung*-oriented teaching), as well as Roberts' description of Vision I and Vision II for scientific literacy (2011), in our analysis.

With regard to the four unique perspectives or views of what is meant by *Bildung* (or a *Bildung*-oriented teaching), we have used (i) a "classical" view of *Bildung* which connects the construct to the writings of Herder, von Humboldt, and Hegel (Liedman, 2002); (ii) Wolfgang Klafki's understanding of *Bildung* (Klafki, 2000a) and approach to didaktik analysis (Hopmann, 2000; Klafki, 2000a, 2000b; Vasquez-Levy, 2002); (iii) Sjöström's (2013) three level model for a chemistry teaching that embodies a "human element", with "critical-philosophical approach" (as level 3) corresponding to an eco-reflexive *Bildung*-oriented chemistry teaching and Vision III; and (iv) Rucker's (2020) understanding of what is meant by a *Bildung*-oriented teaching. Regarding our inclusion of Roberts' description of Vision I and Vision II for scientific literacy, we refer to a systematisation/network recently created by Jesper Bruun (Dolin et al., 2022, p. 20), which presents different aspects of *Bildung* in relation to science education. One significant aspect of *Bildung* connected with science education according to this systematisation/network is an "overlap with Robert's scientific literacy visions" (ibid). We also refer to Sjöström's (2013) alignment of Roberts' Vision I and Vision II for scientific literacy with level 1 and 2 of his three-level model for a chemistry teaching that embodies a "human element".

Subsequent to this analysis step, conclusions were drawn in relation to the occurrence of statements consistent with either the idea of economic goals associated with neoliberalism that are expressed within education or the idea of *Bildung*. Further, conclusions were also drawn where evidence pointed towards a clear relationship existing between these two themes. So that these conclusions could be verified, text excerpts from interview transcripts illustrating the conclusions drawn were identified for each teacher.

3 Results and Discussion

3.1 Teachers' *Bildung*-orientations

Our first research question asked in what aspect can an orientation towards promoting *Bildung* be discerned in Swedish chemistry teachers' work with questions of *what* content is important to learn, *why* it should be taught, and *how.* As a general result, elements were identified in all five teacher interviews that could be related to one or more of the four unique perspectives or views of what is meant by *Bildung* (or a *Bildung*-oriented teaching) and/or Roberts' description of Vision I and Vision II for scientific literacy. However, of relevance to this discussion is the question of *in what aspect* these capacities manifested.

Perhaps the most significant result in this regard was the absence of the moral/ethical dimensions of *Bildung* in four of the five interviews, with only one of the interviewed teachers—John—touching on this dimension, when describing developing students' ability to responsibly participate in society as a collective project in *one* of John's teaching goals.

> *John*: … chemistry knowledge that they should be able to use in some way in their careers… There one can see oneself as being a kind of a part of the building of society, … It's not about the career of the individual but rather that we work in a context, we are dependent upon one another, our choice of what we do, our actions influence … that our use of fossil fuels is not just something that affects us as individuals, but rather how we think about the provision of energy, … that our choices they influence the future for us and for our children.

Drawing from the classical theories of *Bildung*, Klafki has described the idea of "cognitive *Bildung*" as a view of *Bildung* in which the moral/ethical dimensions of the construct are lacking (2000).[3] Indeed, Klafki further related such a view of *Bildung*, in which the development of intellectual knowledge outpaces recourse to "human sense" or responsibility, to a reduction of the natural sciences to instrumental terms only (ibid). Of critical importance in this regard is the idea that human capacities consistent with *Bildung* in the absence of the construct's moral/ethical dimensions are not necessarily used to positive ends (Klafki, 2000a, 2000b).

Regarding the five interviewed chemistry teachers, it is notable that four of the five teachers (John, Alex, Anna, June) linked the development of capacities that can be related to *Bildung* with purely instrumental aims. Thus, John linked the development of a critical posture with the role of school in preparing students for university study. Alex linked the development of student's interest with the possibility of changing a national trend towards a reduced interest in the natural sciences. Anna linked the development of students' taking control over their learning with supporting student's future studies and work. Finally, June linked having an understanding for how life is built up to having the grounding necessary for later university study. In the cases of John, Anna, and June, the development of capacities related to *Bildung* were described within the context of their being tools for student's utilisation in mastering university education and/or work. In the case of Alex, they were described within the context of the politically driven need to produce more natural scientists nationally. In our analysis, such instrumental ends have been interpreted as being consistent with economic goals associated with neoliberalism. Specifically, of education as causing economic growth through school being viewed as an arena for human capital production (e.g. Adolfsson, 2013; Gillies, 2014; Sundberg & Wahlström, 2012). We argue therefore that these particular "*Bildung*-related elements",[4] as described by John, Alex, Anna, and June, are consistent with the idea of "cognitive *Bildung*". Clearly, "cognitive *Bildung*" does not determine unethical or irresponsible action, but at the same time, it does not guarantee that one steps away from it. "Cognitive *Bildung*" ought therefore be seen as a marginalised form of *Bildung*, that in some circumstances may even wholly preclude to *Bildung*.

[3] The German philosopher Julian Nida-Rümelin (2013) has asserted that the *Bildung* of the whole person demands a coherence between cognitive, ethical, aesthetic, and emotional aspects. "Cognitive *Bildung*" might be viewed in this regard as representing an incoherence between these different aspects of the *Bildung* of the whole person whereby the cognitive aspect dominates over the ethical, aesthetic, and emotional aspects.

[4] By which we mean elements identified in teacher interviews that could be related to one or more of the four unique perspectives or views of what is meant by *Bildung* (or a *Bildung*-oriented teaching) and/or Roberts' description of Vision I and Vision II for scientific literacy.

Within a *Bildung* paradigm, learning is viewed as being meaningful to the learner and intrinsically driven, so that content learned connects in an immediate way to their contextual reality, giving learning immediate relevance and value (Lüth & Horton-Krüger, 2000, Deng, 2018). In this view, the linking of subject content to student's everyday lives, with a view to making content matter meaningfully to the student (Yavuzkaya et al., 2022), is necessary if teaching is to open to *Bildung* (Klafki, 2000a, 2000b).

With regard to the present study, all five teachers described linking chemistry content to students' everyday lives. Of the five teachers interviewed, with two exceptions, all examples given were consistent with Roberts' (2007) Vision I for scientific literacy and/or pure and applied chemistry in Sjöström's (2013) three level model for a chemistry teaching embodying a "human element". One example given by John, in which he described how one can create a reflective discussion around the development and use of modern batteries, when teaching electrochemistry, was consistent with Robert's Everyday Coping and thus Vision II for scientific literacy. An example given by June, in which she speculated that students could discuss the impact of the chemical industry on the environment, was also consistent with Robert's Vision II, and indeed, one could argue that this example might also be consistent with "critical-philosophical approach" as the highest level of Sjöström's model (and corresponding to a *Bildung*-oriented chemistry teaching). However, June framed their example within the context of students examining solely the economic impacts. It could equally be argued therefore that this example suggests a reduction in June's view of environmental concerns connected with the chemistry industry to solely an economic perspective. Such a view would be difficult to align with *Bildung*. In view of this—and considering that this example was not a description of their actual teaching, but rather a speculation by June about a possible way of connecting chemistry to societal issues—it is contentious to align this example with level 3 of Sjöström's model.

Thus, no examples given by teachers linking chemistry to students' everyday lives corresponded with Sjöström's (2013) understanding of a *Bildung*-oriented chemistry teaching (as "critical-philosophical approach"), or the author and colleagues' (e.g. Sjöström & Eilks, 2018) description of a critical- or eco-reflexive *Bildung* as corresponding to a critical view of scientific literacy and thus Vision III.

3.2 Contextual factors marginalising *Bildung*

Our second research question asked in what aspect economic goals associated with neoliberalism might hinder an orientation towards promoting *Bildung* in Swedish chemistry teachers' work with questions of *what* content is important to learn, *why* it should be taught, and *how*. Significantly, four of the five teachers named *contextual factors* as negatively impacting their ability to realise *Bildung*-related elements in their visions for their teaching. Crucially, such factors are relatable to economic goals associated with neoliberalism expressing themselves within education.

For example, John described large class sizes, a limited number of available lessons, national tests,[5] the course syllabus, pressure to make sure every student passes the course, and a greater measurement and control of student's knowledge in today's educational system as factors that negatively impact his ability to realise the *Bildung*-related elements in his vision

[5] External examinations are not used in Sweden when students finish secondary and upper secondary school. With a view to promoting comparability in grading on a national level, national tests are used locally by teachers in many subjects (Pettersson, 2004).

for his teaching. Similarly, Jennifer named limited time caused by the need to get through the course syllabus, students' and parents' grade fixation, the demand placed upon them from multiple parties that every student should pass the subject, and a growing discourse in which teachers' salaries in Sweden are connected to the results students achieve. Anna described a need to get through the course content, work formatively, and student's being grade fixated, and June described lacking time and having a lot to get through. In view of an emerging picture of neoliberal values as entangled with science (and Swedish) education (e.g. Gustavsson, 2009; Bencze & Carter, 2011; Lundgren, 2011; Tobin, 2011; Sundberg & Wahlström, 2012; Adolfsson, 2013; Bencze et al., 2014; Carter, 2014; Bazzul, 2016; Hayes, 2016; Carter, 2020; El Halwany et al., 2021; Wallace et al., 2022; Bazzul, 2023), such a result is perhaps not entirely unexpected. What was unexpected, however, was the breadth of factors potentially marginalising *Bildung* in teachers' work that were not contextual, but rather, were *implicit*, that is, factors that are a part of each teacher but outside of their awareness.

In 3.3–3.7 we present and discuss for each teacher the different implicit factors revealed in our analysis.

3.3 John's implict marginalising of *Bildung*

Despite John encompassing the full breadth of *Bildung* in their vision for their teaching, the value they saw *Bildung*-related capabilities as conferring was largely aligned with economic goals associated with neoliberalism.

> *John*: because I work primarily within a university preparatory program, … my thoughts are that they need to develop … a critical posture of being able to reflect about knowledge and not just take it for granted but also [ask] what does this knowledge mean? Mmm. A special relationship to knowledge.

Further, in discussing why they were unable to work more purposefully with developing capacities related to *Bildung* in their teaching, John expressed a belief that one must teach elementary knowledge first before one can connect the subject to relevant societal issues and work with "more developmental" goals.

> *John*: … then one puts in a lot of energy in order to work with the most foundational proficiencies, and of course, one cannot always reach these more developmental goals that are a little further ahead.
> *John*: One is very careful to make sure one teaches all that needs to be taught, and that every student has received the core content … Instead … of the students developing the ability for critical thinking. So it is always a trade-off, what one uses one's time for.

According to Eilks et al. (2013), such an approach can be described as a structure of the discipline (SOD) approach. The approach reflects a traditional approach to science curricula that views "basic concepts and structures of the disciplines […] as the focal points of a curriculum" (ibid, p. 17). Significantly, not only did John's SOD approach seemingly marginalise their opportunity for promoting capacities related to *Bildung*, John further appeared to marginalise *Bildung* by using an activity—a discussion around the development and use of modern batteries—that could potentially open towards the development of capacities related to *Bildung* in the service of their SOD approach.[6]

[6] See Tidemand and Nielsen, 2017, for a related example.

John: In that way one can usually use it as an example when introducing that area … So that one, well, connects it to their, well, to something that feels a little more connected to everyday life for them … It's to get the students to think and reflect … When you've got them starting to think about it you have in some way opened the student, they become more receptive for getting into it and looking at, how is this battery working, what do these chemicals really look like, … So it's a kind of gateway in some way which I have experienced as quite effective, …

3.4 Jennifer's implict marginalising of *Bildung*

Jennifer's vision for their teaching was significantly aligned with a view in which education is seen as an arena for the expression of economic goals associated with neoliberalism.

Jennifer: The purpose of school is to educate individuals so that they can contribute to our society, one can say. […] That they should get sufficient knowledge to be able to continue on from upper secondary school. Get enough knowledge to start working, […] contribute to different spheres in society.

Significantly, *Bildung*-related elements in Jennifer's vision for their teaching could only be linked with the curriculum emphases solid foundations, correct explanations, and scientific skill development as three dimensions of Roberts' (2007) Vision I for scientific literacy.

Jennifer: … not just learn the subject but perhaps learn like to be able to solve a natural science problem. For example, that one maybe can translate to other subjects, some kind of, I don't know, methods.

Of importance in this regard is that the two goals Jennifer described in relation to their vision for their teaching in terms of "what value learning should have for students' themselves" (both being consistent with the curriculum emphasis solid foundations) were according to our analysis in conflict with ideas of *Bildung*. Specifically, the idea that *Bildung* fundamentally entails repeated steps of renewal; that is, coming into a relationship with an aspect of the world that is *Other*, and returning with renewed eyes (Gustavsson, 2014).

Jennifer: … the more one, well, that knowledge, like, … to be able to build upon, to be able to learn something new then one must have something to grab hold of like, something old that one knows, and I think that the more one knows from before the easier it is to grab hold of it in a way.

We argue therefore that *Bildung*-related elements in Jennifer's vision for their teaching are only weakly associated with *Bildung*. In regard of this, we find it noteworthy that during the interview's second part, concerned with teachers' reports of their work to realise their vision for their teaching (the didaktik *how* question), Jennifer spontaneously discussed linking chemistry to student's everyday lives. Although they did not explicitly state this as a goal for their teaching in the first part of the interview, the idea of linking chemistry to student's everyday lives is consistent with Klafki's (2000b) didaktik analysis and Sjöström's (2013) chemistry teaching embodying a "human element". However, Jennifer expressed a lack of efficacy in linking chemistry to student's everyday lives. When asked why they experienced this, they explained that they lacked the time needed to become efficacious. We believe, however, that the following interview segment suggests not only a perceived lack of time but also a lack of intentionality and ambition on Jennifer's part in relation to this aspect of their teaching:

Jennifer: Many years I have thought 'now I'm going to try and connect to reality, try to find things out'. But then the school year begins and such, then I think that I'll start over the summer break, and then the summer break comes and one just disconnects from it all, and then one starts again and so one doesn't find the time anyway.
Interviewer: So you think the cause is a lack of time?
Jennifer: Although strictly speaking one doesn't need to connect the whole course to something all at once. One could use a smaller number of occasions; so I would have the time, but, I don't know, it just hasn't happened.

What we believe to be a weak association with *Bildung* in their vision for their teaching seems to find a parallel therefore in Jennifer's spontaneous discussion about working to connect chemistry to student's everyday lives during the second part of the interview. Drawing from a view of *Bildung* as a counter-concept (Alves, 2019), we would anticipate a weak association with *Bildung* (in a contemporary sense) to be associated with a teacher vision that is dominated by an instrumental view of education (Schnack, 2008). We suggest therefore that Jennifer's significant alignment of education with economic thinking is linked to a marginalising of *Bildung* in their work with questions of *what* content is important to learn, *why* it should be taught, and *how.*

3.5 Alex's implict marginalising of *Bildung*

In contrast to the other teachers in this study, Alex did not express contextual hindrances as affecting their work to realise their vision for their teaching. Indeed, Alex expressed that being a chemistry teacher gave them a great opportunity for being creative.[7]

Alex: And then I like to be inventive … there is so much space for being creative.
Alex: … I think one has so much freedom. There is a content of course, but I think there is so much space as well for being creative, I think that's fun.

That Alex viewed the role of chemistry teacher as an arena for creative expression manifested primarily in the numerous novel methods that Alex described using to promote student's curiosity, interest, active problem solving, and hard work. Importantly, a central goal that Alex expressed for using creative methods in their chemistry teaching was to motivate students to raise their level and work harder to learn more chemistry. One conclusion that can be drawn therefore is that Alex reported realising important dimensions of their vision for their teaching that are related to *Bildung*. Noteworthy, however, in this regard is that a central theme in Alex's vision for their teaching in terms of "what value learning should have for students themselves in their lives" was that students should have fun learning chemistry.

Alex: First and foremost one wants to, I want them to think that it's fun to learn.
Alex: … I try to vary it so that it's fun. I do things in different ways.

Interestingly, Alex pointed out that they wanted teaching chemistry to be fun too.

Alex: … personally I think that I have more fun than just standing and, well. And I think that if the teacher is having fun that will be seen by the students and then I think they will also think it's fun.

[7] It is worth noting that Alex's other teaching subject was within the Arts.

Alex's vision for their teaching in terms of "what value learning should have for students themselves in their lives" is striking because Alex does not extrapolate their answer beyond students having fun learning (chemistry), even though the question fundamentally asks *why* teach? Indeed, Alex's admission that they wanted teaching chemistry to be fun for themselves as well seems to point to an intrinsic drive in Alex to be creative in their chemistry teaching. In this sense, Alex's vision for their teaching in terms of "what value learning should have for students themselves in their lives" may also have been connected with the "value" they saw their novel chemistry teaching having for themselves. We argue therefore that Alex's urge for creative expression as an intrinsic drive in the teacher is a potential pathway through which *Bildung* may be marginalised at an implicit level in Alex's work with questions of *what* content is important to learn, *why* it should be taught, and *how*.[8]

3.6 Anna's implict marginalising of *Bildung*

In discussing the *Bildung*-related element of developing in students the ability to take control over their own learning, described by Anna as their overriding teaching goal, they aligned this capacity with a view of education as driven by economic goals associated with neoliberalism.

> *Anna*: … I want the student's to take control over their learning, … that's something that irrespective of what they choose to do later in life, this ability is something that will help them later in future studies or if they choose to work in some, well, in the workplace for a period. After all it's a, university, I mean, a further education I mean, it's primarily what we are preparing them for, university. So it's primarily that which I'm thinking about.

Significantly, during the second part of the interview, Anna gave a vivid and detailed description of how they worked to develop and evaluate this capacity in their students. Of importance in this respect was their description of using the formative assessment strategy Assessment for Learning (AfL) as a fundamental tool.[9]

> *Anna*: … I work very much formatively, the formative assessment, and it's about, one is thinking, like, key strategies. Mmm, some of the first key strategies are very much about they themselves taking control over their own learning. And much of that is about me having the possibility to give students continual feedback. And then a part of my teaching is about my ascertaining where my students are [in their learning]. What I say is that I don't take a step without knowing where my students are. So I can probably say that I base my teaching on my knowing where my students are.

Interestingly, when discussing another goal for their teaching, that of waking in students an intrinsic curiosity and desire for learning, Anna suggested that their use of AfL compromised their work to develop this capacity. Significantly, our analysis suggests that this latter capacity is more strongly linked to *Bildung* than the former.

[8] This marginalisation can be most simply understood as Alex prioritising their own *Bildung* as a goal of their chemistry teaching.

[9] AfL is a formative assessment strategy that seeks to use assessment in order to support students in their learning. A central idea in AfL is to clarify to students where they currently are in their learning and what they need to do in order to better reach the learning goals the teacher has set for them (see William, 2011, for a review).

Anna: there is a content, a content one has to get through. One want also to give the students the possibility to, one wants to be clear with concretising a criteria that is graded. One wants to be clear in also telling the students what they need to do to reach the next step [a higher grade in relation to a specific criteria]. And of course that takes away a little of the intrinsically-driven learning if one has, partly the students are highly motivated, that easily get this kind of tunnel view, that it's only about grades. Then it's very easy that the focus is there only. 'This is nothing I need because this is nothing that is important regarding the most central [curricular goals]. What is the minimum, like, that I need to reach a certain grade?' It's a little bit like that. They become very strategic.

In view of the fact that Anna described putting a considerable effort into assessing student's ability to take control over their own learning, one could argue therefore that Anna contributed in potentially marginalising the development in their students of an intrinsic curiosity and desire for learning. Of consequence in this regard was that examples Anna gave in relation to their work to link chemistry to student's everyday lives were consistent only with "applied chemistry", that is, level 1 of Sjöström's (2013) three level model describing different approaches to chemistry teaching that embody a "human element".

Anna: … for example, why does an egg become hard when one cooks it, but a potato becomes soft, mmm, and when we later have gone through more, then we return to this question and in that way, I hope I have in some way, that they understand what they can do with this knowledge, …

3.7 June's implict marginalising of *Bildung*

The development in students of a natural sciences view of the world dominated June's vision for their teaching, with such a perspective being seen as opening their student's to relating to the world in a natural sciences way, something which they potentially could use in their future careers.

June: I think one gets much more out of life if one can grasp the whole, because it is much easier to understand it and then be able go in and learn the details of the citric acid cycle for example. … And if they later in life need to learn exactly which hydrogen which moves where … then they can go in and learn it because they have an understanding for how it works and what the purpose of it all is.
June: One would hope anyway that they have this with them, so that they can take, because natural science, it's in all careers. … Well, one can at least hope that they have with them some grounding, so that they can at least understand if something is completely crazy.

Bildung-related elements in their vision for their teaching were therefore predominantly framed within this context; although similar to the other four teachers, June also aligned *Bildung*-related elements with economic goals associated with neoliberalism.

June: … the big thing is that they can also succeed at the next level … And they succeed because they had good tools with them … That's fundamentally our goal, to get them ready so they can succeed at the next stage.

That June framed *Bildung*-related elements in their vision for their teaching within the context of student's developing a natural science worldview as the principal way of comprehending the world (see for example Lee & Witz, 2009) causes us to question the degree to which these capacities can be viewed as reflecting a *Bildung* orientation in June. According to Rucker (2020), a *Bildung*-oriented teaching is fundamentally built upon enabling students to step away from habitualised ways of viewing the world. Whilst we agree that education in the natural sciences can be a pathway to such teaching, we would argue that it cannot be the case if the worldview being taught becomes for the student a singular unquestioned reality. Indeed, Rucker seems to point towards this idea by citing Blankerts' placing of judgement and criticism at the centre of the *Bildung* construct (ibid). Equally significant, Rucker describes today's world as characterised by an "irreducible perspectivity" (p 375), and he claims *Bildung* to require thus the person coming to a *multi-dimensioned* ability to self-determination in order to find their place in such a world (ibid). In view of these ideas, June's predominant framing of *Bildung*-related elements in their vision for their teaching within the context of student's developing a natural science worldview might reasonably be seen as marginalising *Bildung*. Indeed, June continued to frame *Bildung*-related elements predominantly in this way in their descriptions of their work to realise their vision for their teaching as well.[10]

> *June*: At the moment I'm working a little with biochemistry and such and we're talking about enzymes all the time, and so one is trying to do labs that illuminate this thing with for example how does an enzyme work. And then it can be that one is looking at, when one spits in a glass. What happens when one spits on different things and such.

Also of significance in relation to the idea of implicit factors marginalising *Bildung* was June's view of the upper secondary school subject of chemistry as "career oriented", "narrow", and "one level below biology".

> *June*: But chemistry is a little special because it feels more like it's career focused.
> *June*: Chemistry is significantly narrower [compared with General science].
> *June*: I think biology has an advantage there, that it is one level up [compared with chemistry] if you know what I mean?

Crucially, we think this view of the subject could explain the absence of *Bildung*-related elements in all aspects of June's (reports of their) chemistry teaching, with the sole exception being when June discussed teaching biochemistry in collaboration with the subject of biology. Interestingly, during the second part of the interview, June described that it was easier to connect to societal issues when teaching general science (June's other teaching subject) than when teaching chemistry. Indeed, it was at this point of the interview that June described chemistry as being a more "narrow" subject. It is tempting to speculate therefore whether June viewing chemistry the way they did was related to their contrasting of chemistry with general science (and biology).

[10] The one exception to this, in which June speculates that students could discuss the impact of the chemical industry on the environment, was framed by June within an economic perspective (see The exceptions' in 3.1).

3.8 Teachers' implicit alignment with neoliberal values

Table 1 presents a summary of eight (lettered a–h) differing ways in which implicit factors potentially marginalised *Bildung* in their work with questions of *what* content is important to learn, *why* it should be taught, and *how*.

Crucially, our analysis points to the marginalising of *Bildung* for all five teachers through their implicitly aligning different aspects of their didaktik work with a view of education as seen through a neoliberal lens (Table 1—a and b), with the degree of alignment being possibly greatest for Jennifer. We think that this result is consistent with a view that describes the subjectification of (Western thinking) human subjects as strongly impacted by the spread of capitalist principles into subject's private lives, both as consumers and workers (e.g. Freudenberg, 2021; Heron, 2008; Kocka, 2016; Wimmer, 2003). Significantly, such principles are viewed as opening to a reduction of the (Western thinking) subject to a worldview that is defined by a narrow set of truths (Heron, 2008). Amongst these include a view of the world as a commodifiable entity and the subject as relating with entities in the world with a view to their profitable utilisation (ibid). That John utilised activities that could open to *Bildung* in the service of their SOD approach (Table 1—d) could potentially therefore be viewed as an aspect of their having neoliberal values at the level of their implicit beliefs. Interestingly, John's SOD approach to chemistry teaching (Table 1—c) can itself be viewed as related to neoliberal values in education, though not specifically to John having such a perspective at the level of their implicit beliefs. According to Eilks et al. (2013), a SOD approach is connected with the idea of science education as a pathway to producing more scientists and engineers. Such an idea is consistent with economic goals associated with neoliberalism coming to expression in education. In their interview, John did not make salient the idea of chemistry education as a pathway to producing more chemists/chemical engineers. There is no empirical support therefore supporting the idea that their SOD approach was related to such a view. Indeed, a possible alternative explanation might be that John's own science (and chemistry) education drew from a SOD approach, becoming an embodiment of a view of how science education is taught (see for example Levinson & Turner, 2001).

Table 1 Summary of the differing ways in which implicit factors potentially marginalise *Bildung* in the five teachers' visions for their chemistry teaching as well as their (reports of their) work to realise those visions

a. The value to students of *Bildung*-related elements is aligned with a view of education as driven by economic goals associated with neoliberalism[John, Alex, Anna, June]

b. A strong alignment with a view of education as driven by economic goals associated with neoliberalism[Jennifer]

c. A structure of the discipline (SOD) approach to chemistry education[John]

d. Activities that can open to *Bildung* are utilised in the service of a structure of the discipline (SOD) approach[John]

e. *Bildung*-related elements are framed within the context of student's developing a natural science worldview as a principal way of comprehending the world[June]

f. The upper secondary school subject of chemistry is viewed as "career oriented", "narrow", and "one level below biology"[June]

g. The development and assessment of one "*Bildung*-related element" is prioritised over that of a *Bildung*-related element more strongly linked to *Bildung*[Anna]

h. An urge for creative expression as an intrinsic drive within the teacher[Alex]

3.9 Additional factors

Although the first four dimensions in Table 1 can be related to the implicit expression in education of economic goals associated with neoliberalism, the remaining dimensions in Table 1 seem less clearly related in this way. For example, June's commitment to a natural sciences worldview (Table 1—e) might more plausibly be explained through June entertaining a philosophical standpoint that views (experimental) objectivity, and thus the scientific method and scientific knowledge, as a superior pathway to knowing and representing the world (see for example Lee & Witz, 2009). Further, we have already speculated that June's marginalising of upper secondary school chemistry through their contrasting of the subject with general science (their "other subject") and biology (Table 1—f) may importantly underlie their marginalising of *Bildung* as a possibility in their chemistry teaching in all areas of the subject (except for teaching biochemistry in collaboration with the subject of biology).

Interestingly, the idea that the teacher's relationship with their "other subject" may impact the possibility of *Bildung* in their chemistry teaching could also explain why Anna (humanities as second subject) marginalised the development of an intrinsic curiosity and desire for learning by prioritising the development and assessment of student's taking control over their learning (Table 1—g). During their interview, Anna described their vision for their chemistry teaching as being importantly linked to also being a humanities teacher, and that students' taking control over their learning was the fundamental goal in their humanities teaching. Significantly, it was through students often holding beliefs that they could not learn Anna's "other subject" that the idea of taking control over one's learning became so fundamentally important for this teacher. Interestingly, Alex, whose "other subject" was also in the humanities, made only a passing reference to it during their interview. Even though this was the case, one could argue that their expressing themselves creatively through their chemistry teaching was linked to their "other subject". Alex's seemingly intrinsic urge for creative expression, however, seems to be an equally plausible source of influence (Table 1—h).

3.10 Closing discussion

We have thus far established that economic goals associated with neoliberalism manifest in upper secondary Swedish schooling at the contextual level for four of five, and the implicit level for all five participating teachers, potentially marginalising *Bildung* in their work with questions of *what* content is important to learn, *why* it should be taught, and *how*. We have also established that three of the five teachers additionally marginalise *Bildung* in their didaktik work because of factors less clearly associated with the expression of neoliberal values in education.

Significantly, although contextual factors such as large class sizes, a limited number of lessons, and national exams lie outside of the power of each of the teachers themselves, the implicit marginalisation of *Bildung* ought not. Künzli (2000) for example writes that "*Bildung* serves didaktik as a cipher in its concern to synthesise into a consistently coherent whole everything happening within instruction" (p. 46). In view of this crucial link between *Bildung* and didaktik, one could take the view that the five teachers work with questions of *what* content is important to learn, *why* it should be taught, and *how* ought to be tied to a didaktik work that seeks *with intention* to guide students towards their own *Bildung*. The results of our analysis seem to point however towards absence of such an intention on the part of the five chemistry teachers, that is, an absence of a clear *Bildung*-oriented *didaktik praxis* (see for example Künzli, 2000; Sjöström & Eilks, 2018; Deng, 2021).

Whilst acknowledging that the Swedish curriculum and syllabus for upper secondary school chemistry teaching express different purposes (see for example Knekta et al., 2022), our reading of the curriculum calls attention to the development in students of a critical positioning and agency in relation to human activity, environmental impacts, global environmental issues, sustainability, and the role of chemistry. Questions of how our ways of living and working impact the world; how they can be shaped to create sustainability; how science and societal development interact and connect to questions of climate, the environment, and sustainability; and how ethics as well as issues of sustainability connect with different ways we employ and apply chemistry are all elements of chemistry (and science) education in Swedish upper secondary schools (Skolverket, 2011). Swedish upper secondary school chemistry teachers have thus curriculum and syllabus support for developing a chemistry teaching that recognises the complexity characterising the discipline of chemistry's position in relation to risk society and the Anthropocene.

In our view, such a chemistry teaching can be informed by teachers working with the *intention* of transforming content for *Bildung* in their chemistry teaching, e.g. critical- or eco-reflexive *Bildung* (e.g. Sjöström & Eilks, 2018; Sjöström et al., 2016, 2017). For the five teachers in our study, however, this does not appear to be the case. Rather, the results of this study seem to point towards different factors impacting the five teachers' didaktik praxes, with one factor in particular, that of economic goals associated with neoliberalism, impacting four of the five teachers contextually, and all five teachers implicitly, that is, at a level of knowing outside of their awareness. Significantly, neoliberal values have increasingly impacted education in the Nordic countries (e.g. Sundberg & Wahlström, 2012; Krogh et al., 2021; Wahlström, 2023) borne on a view that education generates competitive advantage and thus economic growth (Gillies, 2014; Krogh et al., 2021). Importantly, this can account for the contextual factors explicitly raised by four of the five chemistry teachers as marginalising their work to realise *Bildung*-related elements in their teaching. However, neoliberal policy in education cannot, we think, explain the implicit factors that marginalise *Bildung* in the five teachers' work with questions of *what* content is important to learn, *why* it should be taught, and *how*. Rather, it is neoliberal values at the level of the five teachers' implicit beliefs that we think can best explain these factors. We have argued that such beliefs can be related to the subjectification of (Western thinking) human subjects as strongly impacted by the spread of capitalist principles into subject's private lives (Heron, 2008; Kocka, 2016; Wimmer, 2003).

Significantly, Heron (2008) has described such principles as opening to a reduction of the (Western thinking) subject to a view of the world as a commodifiable entity and the subject as relating with entities in the world with a view to their profitable utilisation. Interestingly, in their description of their teaching, John describes utilising an activity that could potentially open towards *Bildung*, a reflective discussion around the development and use of modern batteries, in the service of a structure of the discipline (SOD) approach (Eilks et al., 2013). Further, John, Alex, Anna, and June framed, in different degrees, the *Bildung*-related elements they defined in their visions for their teaching either as capacities they envisioned students utilising in the future in the service of mastering study and/or work, or as capacities that served a national need to produce more scientists. We wonder therefore whether these might be viewed as examples of a reduction of *Bildung*-related elements to commodifiable entities only and thus an expression of the reduction of the (Western thinking) subject by economic neoliberal values.

Importantly, Wimmer (2003) has discussed a commodification of *Bildung* in the context of an education dominated by an economic view. Seen in the context of this study, a commodifying of *Bildung* as an educational concept centrally bound to the didaktik tradition

marginalises didaktik as a freedom of method for transforming content for *Bildung*. More likely, we think, is that the first four implicit factors in Table 1 point towards economic neoliberal values at the level of teachers' subjectification commodifying *Bildung* and thus disempowering the five chemistry teachers in relation to a teaching praxis that seeks with intention to guide students towards their own *Bildung*.

4 Conclusions

In view of the complexity characterising the discipline of chemistry's position in relation to risk society and the Anthropocene, we think that capacities like critical reflexivity, critical-democratic awareness, sociopolitical action, and eco-justice are examples of the kinds of capacities that chemistry teaching should seek to promote in students (see for example Sjöström et al., 2016, 2017; Sjöström & Eilks, 2018; Quiroz-Martinez, 2023). Indeed, the Swedish curriculum and syllabus for upper secondary school chemistry to some extent support (broadly speaking) a teaching that promotes such capacities (Skolverket, 2011).

In Sweden, *Bildung* is viewed as being fundamentally tied to the Nordic and Germanic didaktik tradition and the praxis therefore of teachers' actively engaging in questions of *what* content is important to learn, *why* it should be taught, and *how* (Wickman et al., 2012). Our investigation of five Swedish chemistry teachers' work with questions of *what* content is important to learn, *why* it should be taught, and *how* points however towards economic goals associated with neoliberalism at the level of teachers' implicit knowing (and thus outside of their awareness) as orienting teachers to view *Bildung*-related elements in their chemistry teaching as commodifiable entities, disempowering thus these teachers in relation to the possibility of a teaching praxis that seeks with intention to guide students towards their own *Bildung*.

In view of the idea that *Bildung* (as counter-concept) embodies critical and resistant elements that resist the narrowing of human perception of reality (Wimmer, 2003), the possible commodification of *Bildung* by the five chemistry teachers—in a country where *Bildung* is historically tied to its educational tradition—provides empirical support for the idea that *Bildung* as a counter-concept may be threatened in Swedish schooling (see for example Sjöström & Tyson, 2022). We believe that this points to a possible risk in relation to the idea of promoting a chemistry teaching that can orient students in relation to ideas of complexity, risk society, and the Anthropocene. At least one that can open to developing capacities such as critical reflexivity, critical-democratic awareness, sociopolitical action, and eco-justice. Some readers, as chemistry (or science) teachers, may feel that opening to the development of such capacities in chemistry (and science) teaching is a fundamental part of our species orienting itself to limiting negative impacts on the planet that are viewed as being a consequence of human activity. We believe therefore there is a need, not only within the Nordic and Germanic didaktik tradition, but wherever education finds itself entangled with neoliberal policy (contextually and implicitly), for a chemistry (and science) teaching that seeks with intention to guide students towards their own *Bildung*.

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Data Availability The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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