Towards Transdisciplinary Didaktik – Didactic Modelling of Complex Controversial Issues Teaching for Reflexive *Bildung* and Sustainability

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Different areas of subject-Didaktik has contact points to other educational sciences such as general Didaktik, pedagogy and education studies, the school subject/subject area, and practical teaching experience. Many areas of subject-Didaktik have in recent decades evolved from mainly practice-based methodology to quite independent research fields. This applies, for example, to the field of science education. Part of this field focuses on research on teaching and learning about interdisciplinary socio-scientific issues (SSI). Such an orientation can be connected to similar orientations in other areas of subject-Didaktik. This meeting point between different research areas of subject-Didaktik is an example of 'general subject-Didaktik'. The focus in this paper is even beyond; it is on transdisciplinary Didaktik, where the content (in a broad sense) is central, but where the context is beyond the individual school subjects. We are especially interested in didactic models for how complex controversial issues can be used (didactic modelling) to build bridges across different areas of content and school subjects in support of reflexive Bildung and sustainability. We give examples of didactic models, which were developed during a study about the didactical dilemmas that teachers from different school subjects experienced when they were teaching complex controversial issues.

Introduction

This paper is subdivided into five parts: (i) We start by describing the concepts of critical (scientific) literacy and reflexive *Bildung*. (ii) Then we discuss commons between different fields of subject-*Didaktik*, which can be called 'general subject-*Didaktik*'. An orientation that even transcends subject borders can be called transdisciplinary *Didaktik.* (iii) In the third part we explain the concepts of didactic models and modelling. (iv) This is followed by a part about controversial issues teaching. (v) Finally, we conclude the paper by describing examples of didactic modelling of complex controversial issues teaching for reflexive *Bildung* and sustainability. Because we both are schooled science teachers we mainly take examples from the field of science-*Didaktik*/science education, but our message transcends this specific subfield of subject-*Didaktik*.

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Critical literacy and reflexive *Bildung*

We live in a risk society (Beck, 1992), in which citizens, professionals and politicians must be able to manage health and environmental risks. Scientific knowledge is one of several necessary knowledge bases (Elmose & Roth, 2005). In line with this, science education must be designed with the purpose of educating critical-democratic citizens (Aikenhead, 2006; Sjöström & Stenborg, 2014; Sjöström & Eilks, 2018). Hodson (2011) has argued for a critical scientific, technological and environmental literacy, shortened to *critical scientific literacy*. More generally, Lewinson et al. (2002) suggested the following broad definition of *critical literacy*: (1) disruption of the commonplace, (2) interrogation of multiple viewpoints, (3) focus on socio-political issues, and (4) action and promoting social justice. The thinking and acting of autonomous, critical thinking and ethically-aware citizens is related to the concepts of critical citizenship (Johnson & Morris, 2010) and *Bildung*. The aim of critical scientific literacy is to have knowledge and abilities for being an autonomous, responsible-taking and action-competent citizen, working in the interest of socio-ecojustice and global sustainability (Hodson, 2011).

Bildung is the German and international term for an educational-philosophical key idea in Germany, Central Europe and Scandinavia (Sjöström, Frerichs, Zuin & Eilks, 2017). According to Wimmer (2003, p. 185) "*Bildung denotes whatever is not covered by the other central concepts of pedagogical theory such as socialisation, education, and instruction*"; it stands for them all and also something more. It is, according to him, "*the central critical concept of modern pedagogy*". Due to its both educational and political dimensions "*it allows us to say something different about education*" (Biesta, 2002, p. 344). For Elmose and Roth (2005, p. 21), *Bildung* "*involves competences for self-determination, constructive participation in society, and solidarity towards persons limited in the competence of self-determination and participation*".

According to Biesta (2012a, p. 817) "*the role of the individual in the process of Bildung, […] has to be understood as a reflexive process*", i.e., a process where the individual establishes both a relationship and a critical stance towards the existing culture and society. In this process of *subjectification* the individuals become "*autonomous – subjects of action and responsibility*" (Biesta, 2012b, p. 7). This phrase "*tries to capture a conception of human subjectivity that is not selfish or self-centered but always understood as being in responsible relation with other human beings and, by extension, with the natural world more generally*" (Biesta, 2013, p. 739). Biesta (2012b, p. 16) describes this as "*highly political, as it intervenes in and reconfigures the existing order of things*". To specify the meaning with *Bildung* today, we have to base it on the fact that we live in a globalised risk society with many global and ecological challenges (Taylor, 2017; Sjöström et al., 2017; Roselius & Meyer, 2018). Sjöström (2018a) has called such an orientation reflexive *Bildung*.

In addition to scientific concepts and models, which is in focus in traditional science education, scientific processes and societal contexts should also be emphasised in socio-critical and reflexive *Bildung*-oriented science education (Sjöström & Eilks, 2018). In practice, it would mean including more ethical and socio-political

perspectives in the teaching, and the focus would be on problematisation, understanding uncertainties, and balancing the benefits and risks of science.

General subject-*Didaktik*

Based on the thinking of the German *Bildung*-scholar Wolfgang Klafki, the *Bildung* and *Didaktik* concepts are very closely related to each other (see e.g. Fischler, 2011; Jank, 2014; Vásquez-Levy, 2002; Sjöström & Eilks, 2018). This is a critical-hermeneutic *Bildung* concept framed by *epoch-typical key issues*, such as the global challenges. Sjöström (2018b) advocates a critical-reflexive approach to *Didaktik*, with emphasis on analysis and reflection, rather than an instrumental approach where focus is on implementing effective teaching methods.

Different areas of subject-*Didaktik* has contact points to other educational sciences such as general *Didaktik*, pedagogy and education studies, the school subject or subject area, and practical teaching experience. In a recent article one of us discussed what subject-*Didaktik* is, and could be, and presented a framework for *Didaktik* in an integrative teacher education (Sjöström, 2018b). In this, subject knowledge is taught together with knowledge for the teacher profession, mainly *Didaktik*. The framework, which was developed with inspiration from Klafki's didactic analysis, consists of ten analytical areas for developing subject-*Didaktik* in different teacher education subjects. The analytical areas can also be used as guides for research in subject-*Didaktik*, which is developed to very different degrees in different sub-areas. General subject-*Didaktik* stands for aspects common for many/all subject-areas of *Didaktik* (e.g., Kansanen, 2009; Wickman, 2012; Sjöström, 2018b).

In recent decades, *Didaktik* of several subject-areas have evolved from mainly practice-based methodology to quite independent research fields. This applies, for example, to the field of science education. Part of this field focuses on teaching and learning about interdisciplinary socio-scientific issues (SSI) (see e.g. Pedretti & Nazir, 2011). Similar thoughts have also evolved in other areas of subject-*Didaktik* and we will generally discuss it as *controversial issues teaching* (see further below). This meeting between different areas of subject-*Didaktik* is an example of general subject-*Didaktik*. Focus is on subject-content knowledge (in a broad sense), but when this is in between several disciplines or even beyond traditional disciplinary knowledge, we call it *transdisciplinary Didaktik*.

Important to all sub-areas of subject-*Didaktik* are didactic models. We will discuss and describe controversial issues teaching based on some didactic models and therefore we start with a more general description of didactic models and modelling. *Didaktik* can be seen as the teachers' science (e.g., Ingerman & Wickman, 2015). This should be based on research approaches from the humanities and social sciences, in addition to a knowledge base in and about the mother disciplines. Furthermore, it is also a design science and like in other design sciences modelling is central.

Didactic models and modelling

Two fundamental didactic models are the didactic questions (Why? What? How? etc.) and the classical didactic triangle (teacher-content-student) (see Figure 1), but there are many more, both comprehensive and detailed, abstract and concrete, and general and subject-specific (e.g., Jank & Meyer, 2003).

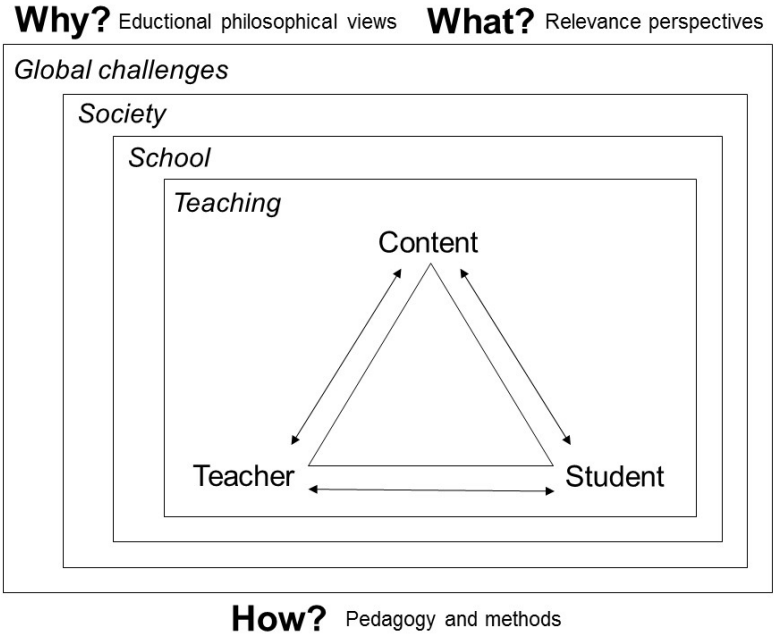

Figure 1. Two fundamental didactic models, the didactic questions and the classical didactic triangle in an expanded form. The figure is constructed by Sjöström.

Recently, we image-Googled 'didaktisk modell' (the Swedish term for 'didactic model') and found several images/models. An example of an image that we do not mean is to be regarded, as a didactic model was a demonstration model for teaching (a plastic skull). At the same time, there were a number of images on didactic models according to our view. Some examples are the didactic triangle, a didactic relationship model, a four-quadrant matrix for assessment, a model for overall lesson planning and a model that can be seen as a thinking tool.

Didactic models can be used, both as analysis tools and as tools in planning of teaching (e.g., Jank & Meyer, 2003; Wickman, 2014). Models based on the didactic questions strengthen teachers' ability to make well-considered didactic choices. Almqvist, Hamza and Olin (2017, p. 21) write (our translation): "*Didactic models can look different and have different purposes. In particular, they should enable didactic analysis of any part of the teaching, such as the selection of teaching content, planning of how the content should be realized in the classroom, how the teaching should be assessed or to understand what happened during the lesson, why it happened and how the teaching could be modified*". There are also more comprehensive didactic models on e.g. subject-*Didaktik* fields and dimensions, and comparisons between different teaching traditions, teacher competencies and *Bildung* views, respectively.

Examples of research-based and teaching oriented didactic models are organizing purposes (Hamza, Palm, Palmqvist, Piqueras, & Wickman, 2018), companion meanings (Lundqvist, Almqvist, & Östman, 2009), and didactical dilemmas (Rydberg, 2018). These examples have the potential to change the practice, but the practice will also affect the models. Such interaction between theory and practice can be called *didactic modelling* (e.g., Ingerman & Wickman, 2015).

In Denmark, the term has been used for research-based development of teaching practice. Blomhøj and Højgaard Jensen (2007, p. 26) wrote (our translation): "*Didactic modelling is our term for a systematic, research-based and reflected development of an education practice*". In other words, it means that subject-*Didaktik* knowledge is developed by teachers in collaboration – in one way or another – with *Didaktik* researchers (e.g., Ingerman & Wickman, 2015; Hamza et al., 2018) and it creates opportunities for teachers' systematic development of their teaching. The starting point is always one or more didactic models that are tested and refined in school practice (Sjöström, 2018b).

Didactic models can be traced back to Klafki's didactic analyses in the late 1950s with five areas of questions (Klafki, 1995; Sjöström & Eilks, under review). Ingerman and Wickman (2015) describe didactic models as a way of introducing teachers to a more general form of didactic analysis. Teachers' challenges are part of a *dilemmatic space* (Fransson & Grannäs, 2013) in which the teachers' dilemmas are ever-present. Fransson and Grannäs (2013) described that teachers in their daily work often end up in dilemma situations. The teacher must deal with formal laws and regulations as well as more informal work routines. Furthermore, the teacher must balance different purposes of teaching towards each other, focusing on the different functions that education should meet, i.e., qualification, socialization and – already mentioned – subjectification (Biesta, 2009).

Controversial issues teaching

Since the 1970s there is a research area that internationally is called *controversial issues education* (Ljunggren, Unemar Öst, & Englund, 2015). Many social issues are characterized by that there are no absolute answers, but strong views on the matter by different stakeholders. To be interested, the issue should be of socio-political relevance. In controversial issues there are not only knowledge-based contradictions, but also a political dimension where opposites are based on the participants' norms, positions, cultural habits, and other experiences. Huddleston and Rowe (2015) described complex and controversial social issues as issues that create strong emotions and tensions in society, since they in most cases contain values and ethical reasoning.

Controversial issues teaching has been practiced and studied in both social science and science classrooms, as well as in the field of environmental and sustainability education (ESE), although the names differ in different subject fields (see further below). Therefore it is appropriate in cross-disciplinary thematic work in schools and is interesting for transdisciplinary *Didaktik*.

Different school subjects have different starting points and perspectives. Therefore the emphasis in controversial issues teaching differs in different school subjects. In a science classroom the focus is primarily on how science is related to ethics and society. In social science education, it is primarily the socio-political content of the issue that is at the center, while ESE typically has an interdisciplinary focus on the weighting of social, economic, and ecological dimensions. Through a teaching approach oriented towards eco-reflexive *Bildung* (Sjöström et al., 2016; Sjöström et al., 2017; Sjöström & Eilks, 2018; Sjöström, 2018a) one can find a fruitful combination for interdisciplinary teaching.

One research area of special relevance for social science education is citizenship education. Recently, Olsson (2016) identified three traditions within this subfield. These three can be connected to Biesta's (2009) three functions of education. They are a more socializing tradition, a more disciplinary oriented tradition, as well as the tradition of *reflective inquiry*. The latter focuses on developing critical thinking through interdisciplinary working methods.

The dominant model for working with controversial issues in science education is referred to as socio-scientific issues (SSI). It is complex and relevant social issues with a science base (see e.g. Ratcliffe & Grace, 2003; Zeidler et al., 2005; Eilks, 2015). However, it is not a uniform teaching model. Although the teaching has the same origin, there are several different orientations on such teaching (e.g. Pedretti & Nazir, 2011). Simonneaux (2014a) has discussed different orientations of SSI-education using a continuum 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 sessions in science and humanities*" (Simonneaux, 2014b, p. 106). In the middle of Simonneaux's (2014a; 2014b) 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. philosophical reflection and socio-political activism.

Recently, Levinson (2017) compared SSI with other science-society education approaches like STEM (Science-Technology-Engineering-Mathematics), SAQ (Socially Acute Questions), and STEPWISE (Science & Technology Education Promoting Wellbeing for Individuals, Society & Environments). He described the education purpose of STEM to be providing human capital, that of SSI to be the development of scientific knowledge needed for socio-scientific reasoning, that of SAQ to be to develop a critical discourse, and that of STEPWISE to develop knowledge for activism and socio-ecojustice. Compared to Simonneauxs' continuum mainstream STEM is at the cold end, mainstream SSI in the middle and SAQ and STEPWISE at the hot end. In a similar organizer, Sjöström and Eilks (2018) recently used the concepts of Vision I, II and III of scientific literacy. Vision I is at the cold end and Vision III at the hot.

Vision I and II relates to Roberts' (2007) two classic visions, while Sjöström and Eilks (2018) introduced a third that they called *Vision III*. This vision includes critical aspects that aim at philosophical reflection and socio-political actions. Science education based on eco-reflexive *Bildung* and Vision III aims for both students and teachers to have a holistic, ethical and political attitude regarding the relationship between science, technology, society, and environment (e.g., Sjöström et al., 2016). One consequence of this is that subject teaching must be open to orienting itself towards transdisciplinary perspectives and subjectification. At the same time, the qualification function of education is also important (Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013).

In a recent literature review, Ottander (2015) discussed various challenges with SSI teaching. In student discussions there is a risk that the science content will disappear when the students focus on ethical reasoning and own experiences, especially if they are relatively free in their discussions. At the same time, when there is too much focus on the science content it can impede environmental and socio-political aspects of the issue (Jensen & Schnack, 2006; Osborne & Dillon, 2008). In SSI teaching, the students should have access to a scientific research base, but Nielsen (2012) claims that the students' answers will not only come from rational scientific reasoning; they will always be strongly influenced by the individuals ideological and ethical views and own experiences.

In this type of teaching, the teachers are facing many didactical dilemmas and they have to make didactic choices (Rydberg, 2018). For example, it could be about to what extent the teachers in the discussions should primarily emphasize learning of explicit content knowledge, whether they are to develop the students' skills about critical thinking or if they should primarily focus on experiencing socio-political participation. The teachers have to find a balance of working with disciplinary content, convey the established social, political and cultural values of the society, and at the same time open up for alternative ways of thinking and acting.

In hot SSI teaching, the teacher may need to handle strong emotions, a changing teacher role and complex assessment activities. In order to do this, the teacher needs to be aware of both the advantages and disadvantages of the various didactical options available. If this awareness is lacking, the teacher can end up in unexpected and difficult situations, which in turn may cause the teacher to opt out of this form of teaching in the future (Rydberg, 2018).

Bencze and Alsop (2014) are editors of an anthology oriented towards critical, radical and 'activist-oriented' science and technology education. They discussed four maxims for such education praxis: (1) contemporary conditions, (2) democratic political theory, (3) subjectivities and agency, and (4) morals and ethics. The framework of their book can be said to be *Bildung*-oriented, although relevant subject matter content could have been pronounced even more (one exception is the chapter by Levinson, 2014). Some keywords describing the anthology are sustainability discourses, science and technology studies, citizen science education, critical pedagogy, transformative learning, SSI, reflexive inquiry, and research-informed activism-projects (Bencze & Alsop, 2014). However, the concept of *Bildung* was not used, which can be explained

with the fact that none of the authors are from German-speaking countries nor from Scandinavia, and only a few of them from Europe.

Didactic modelling for eco-reflexive *Bildung*

Examples of broader didactic models, which takes the global challenges into consideration, are the already mentioned STEPWISE framework for activist science and technology education by Bencze and Carter (2011), the so called SSIBL-model developed by Levinson and the PARRISE consortium (2017), a model of socio-scientific sustainability reasoning (S^3R) by Morin et al. (2014), and a framework for socio-critical and *Bildung*-oriented science teaching by Eilks and his coworkers (Marks et al., 2014).

Here we will give one example of a more specific didactic model, which prepares teachers to work with controversial issues teaching. This model was developed based on ideas of transdisciplinary *Didaktik* much in line with the broader didactic models described above. More specifically it was developed based on a research study, which followed groups of teachers within an EU-funded ERASMUS+-partnership (Rydberg, 2018). In this partnership, teachers from different school subjects conducted intended transdisciplinary teaching about complex and controversial issues. The teaching in five schools, with students aged 12-16 years, in five different countries were compared. The overall research design was inspired by models where researchers and practitioners cooperate and share responsibility and iterative systematic investigations was done. The work at the schools was done in three cycles, where each of these ended with a transnational meeting with both teachers and students. In conjunction with these, data collection was done, primarily using focus group interviews.

Teachers and students worked with different complex controversial issues containing both scientific, technical and social science content, as well as socio-political and ethical aspects. Through the student tasks the students were placed in a scenario where they landed on an imaginary and newly colonized planet named *PromethEUs* (Rydberg, 2018). On this planet, students should together create a new society, which meant that the issues were mainly at a structural level. An intended companion meaning of the teaching was that the students would gain insight into the fact that political decisions on complex issues like these – with both scientific, social, economic, political and ethical aspects – is not about 'right or wrong'. Rather it is about weighing the advantages against the disadvantages and in this process try to make reasonable and acceptable decisions.

The issues were deliberately chosen to be complex and controversial. They are socio-dilemmas where no definite answer exists; instead all possible solutions have both positive and negative consequences. The design of the student tasks strove to develop the students' critical thinking abilities, which obviously are prerequisite abilities in order to be able to independently make decisions and express ethical and political standpoints. Students should also be given opportunities to take their own position in the issues.

Through focus groups and participant observation, the study aimed to describe the appearance of various didactical dilemmas that teachers encountered in the dilemmatic space (Fransson & Grannäs, 2013). A favourable outcome of using four quadrant matrixes in the concluding focus group interview made the basis for the more specific didactic model, which is shown in Figure 2.

The model is a discussion tool, which consists of didactical dilemmas that teachers may face in their teaching practice. Two related dilemmas were combined into an open four-quadrant matrix. Each axis form a continuum between two extreme positions in each dilemma. In each of the four-quadrant matrix there is a statement from fictional teachers. Each teacher statement is representing an 'extreme' position according to the dilemmas. For instance, one matrix focuses on didactical dilemmas related to student-centred instruction versus more teacher-centred approaches, while another one deals with didactical dilemmas concerning to what degree the teacher should be objective, neutral, or take a stand in the discussions (Rydberg, 2018).

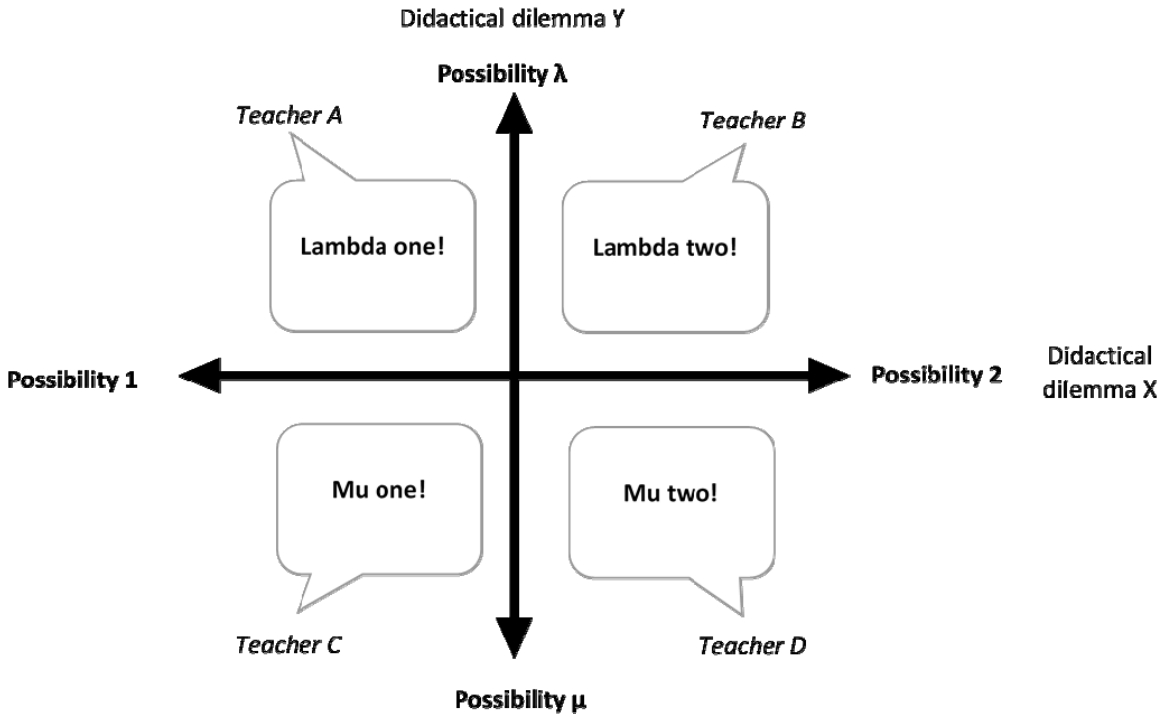

Figure 2. A general didactic model, which – when filled with two didactical dilemmas – can be used to prepare teachers to work with complex controversial issues teaching (see further Rydberg, 2018)

Obviously, teachers are rarely in just one place in the four-quadrant matrix. Rather they move in the area between the extremes. The idea of the tool is to use four quadrant matrixes and the fictional teacher statements to start a discussion, not to pinpoint an exact position for a teacher. Each four-quadrant matrix contains supplementary questions and the idea is that these among the participating teachers will lead to an exploratory discussion of possible intentions and objectives of the fictional teachers. There are also additional questions about what consequences different positions may have. Finally, there are questions of a more normative nature about what may be desirable in the different didactical dilemmas (Rydberg, 2018). Inevitably, the

discussion will lead to that the individual teacher in the professional development activity will reflect on her or his own didactic choices and her or his own positions regarding these didactical dilemmas.

The matrix design opens up for reflections about and discussion concerning different options in the quadrants and is therefore a tool for discussions of pros and cons with different teacher views and positions. A possible example of an axis (i.e., a didactical dilemma) is focus on disciplinary content knowledge on one side and focus on more general skills development on the other side. This tension is related to the tension between so called *material* and *formal Bildung*. Already mentioned Klafki argued for a position mixing these to views and called it *categorical Bildung* (Sjöström & Eilks, under review).

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