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Addressing student conceptions in evolution classes: professional vision practices of preservice and in-service biology teachers

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Abstract

Background: In evolution education, consensus is widespread that diagnosing and addressing well-known student alternative conceptions is particularly important. As classrooms are complex environments with many activities happening simultaneously, noticing and interpreting situations relevant to student thinking is important for addressing student conceptions. This ability can be conceptualised as professional vision. Science educators must understand teachers' status quo regarding their professional vision to identify aspects of teacher education and professional development.

Results: The central concern of this qualitative-reconstructive case study is to describe and better understand how preservice and in-service biology teachers are enacting their professional vision regarding student alternative conceptions and addressing them in evolution class. For data collection, a video clip without any further specific instructions was used as a stimulus for 31 group discussions and 9 individual interviews with 115 preservice and in-service biology teachers. The data were analysed using the documentary method. Of the 40 cases available, 15 were fully interpreted and used for typification. Regarding theoretical saturation, our analyses of the opening passage and other transcript material relevant to the research question for the remaining 25 cases did not lead to any new insights into previously reconstructed orientations or could no longer contribute to the analytical differentiation. The comparative analyses show that in all cases, two key issues could be reconstructed: (1) the relation of teaching and learning scientific norms and (2) the relation of student conceptions and scientific norms. These two issues are consistently processed in an evaluation mode. Across all cases, the participants assess the teacher's actions and the student learning process. The reconstructed types differ in the importance attributed to student conceptions. Student conceptions are constructed, for instance, as indicators of subject-specific knowledge gaps that need to be filled, as a teaching problem, as something that must be removed or changed, or as coexisting experiential knowledge.

Conclusions: We conclude that the discussion of and reflection upon professional vision practices is an important task for teacher education. The study of cases using lesson videos and a professional development programme called video clubs seems promising because these approaches offer possibilities for addressing many of the teacher education challenges to which our results point.

Keywords: Classroom video clip, Documentary method, Evolution, Implicit knowledge, Professional vision, Teacher professional development, Student conceptions, Tacit knowledge, Teacher education, Teleology

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Introduction

Evolution is discussed as a content field of particular importance for science education (Nationale Akademie der Naturforscher Leopoldina 2017; American Association for the Advancement of Science 2006). Addressing the question of how students explain evolution, compared to evolutionary biology, is important for teaching evolution (Harms and Reiss 2019). Since in evolution classes many different actions occur simultaneously, teachers should be able to see and understand issues related to addressing student conceptions. Teachers should notice what students understand in terms of the content and identify appropriate preconceptions and learning barriers. To describe and explore this ability of preservice and in-service teachers, the concept of professional vision, developed by anthropologist Goodwin (1994) can be used. Professional vision is discussed as an important aspect of quality teaching, as it influences whether and how teachers notice and attend to student thinking while teaching (van Es and Sherin 2010). In addition to the importance of knowledge about student alternative conceptions, professional vision can be justified and legitimated by the educational policy guidelines included in German standards of teacher education (Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland 2019a, b).

In the context of teacher education, preservice and in-service teachers see (other people's) lessons individually, but professional vision is expressed in social contexts because it becomes significant when different people talk about their views, e.g., in the context of lesson debriefings in practice phases during studies. In these social situations of teacher education approaches to professionalisation are possible. Therefore, we assume, in line with Goodwin (1994), that a sociological perspective using a theory of social practices (Reckwitz 2002) is appropriate for the conceptualisation of professional vision as a social practice. From this perspective, unconscious, self-evident routines of action as well as experiential and reflexively unavailable knowledge influence the different perspectives on lessons and selective perception. This kind of knowledge, which can be referred to as tacit knowledge, enables routine action, since teachers intuitively know how to understand and react. For this reason, the tacit knowledge that structures this practice is of particular importance.

In general, this qualitative reconstructive case study explored preservice and in-service biology teachers' professional vision by examining *how* they talk about student alternative conceptions regarding evolution and addressing them in the classroom after having watched a video clip. We used group discussions and individual interviews to collect the data. The central concern of this study, which uses a qualitative reconstructive approach based on the documentary method (Bohnsack 2010), is to better understand professional vision practices and reconstruct action-guiding tacit knowledge. Beyond describing each individual case, this methodical approach, especially comparative analyses, makes it possible to generalise reconstructed tacit knowledge through a typification without applying a priori categories to the data. Generalisation in the form of typification can summarize the tacit knowledge that is of general importance to the practices of teachers' professional vision. For science educators, knowledge about the types of teachers' professional vision is a relevant source for better understanding their learners' status quo and for identifying aspects of teacher education and professional development. For this purpose, the professional vision practices reconstructed in the study are related to evolution education and professional theoretical norms to determine fits and differences that should be addressed in teacher education.

Theoretical considerations

Teaching evolution means addressing student conceptions

The consensus in the evolution education community is that teaching evolution is particularly challenging. Research has identified several reasons for this. One is the assumption that evolution is difficult to learn, as it is complex and counterintuitive (Harms and Reiss 2019). What has proven itself in our everyday conceptions often turns out to be incorrect in an evolutionary biology context. Especially in the field of evolutionary biology, diverse student alternative conceptions have been demonstrated extensively and empirically regarding the key, core, and threshold concepts (Tibell and Harms 2017; Nehm and Reilly 2007; for an overview: Harms and Reiss 2019). Student learning of these scientific concepts might depend on the extent to which student alternative conceptions are linked to teaching in the sense of constructivist teaching–learning theories (Duit and Treagust 1998). Thus, science teachers must know how their students understand evolution so that they can develop effective ways of addressing these conceptions. For the present study, two categories of student alternative conceptions are of particular importance. These categories have been found to be most common and to occur in different teaching contexts. First, students transfer human characteristics, usually mental abilities, to nature

(anthropomorphic conceptions), e.g., when assuming an intentional phylogenetic adaptation of individuals. In this context, anthropomorphisms contrast with the scientific norms of objectivity, neutrality, and freedom of value (Tamir and Zohar 1991). Second, biological explanations can be made about the purpose, purposefulness, or necessity living being adaptations (teleological conceptions), although these explanations contradict the scientific principle of causality and mechanistic explanations. Students often explain evolutionary processes by interpreting the function of a characteristic as the cause of its development (Kelemen 2012). When analysing student teleological explanations, acceptable and unacceptable forms of teleology must be distinguished (González Galli et al. 2020; Kampourakis et al. 2020; Trommler and Hammann 2020). Kampourakis (2020, p 11) distinguishes between illegitimate design teleology and legitimate selection teleology based on natural processes. Criteria are discussed to distinguish between them (e.g., Brock and Kampourakis 2022).

The research on student conceptions and how to address them in teaching–learning processes is a central field of international research in science education (Vosniadou 2013; Levrini and Tasquier 2019) and is considered very fruitful for teaching practice (Schrenk et al. 2019). To address student alternative conceptions, different theoretical frameworks are discussed, which are described, as conceptual change, conceptual growth, or conceptual reconstruction (Vosniadou 2013). These approaches represent the guiding paradigm of research on teaching and learning and are characterised by theoretically interesting contradictions and conflicts (Duit and Widodo 2013). They all share the expectation that considering student conceptions increases the effectiveness of student learning and understanding the concepts and mechanism of evolution. A key difference is the impact attributed to student conceptions of teaching and learning scientific norms in each approach. The question of the decisive role of student alternative conceptions for the teaching–learning process is answered in different ways, depending on the approach and the context, e.g., they are seen as a learning opportunity (e.g., Duit et al. 2012) or as a central learning obstacle (e.g., Kampourakis et al. 2012). Another key difference between the approaches is the target in addressing student alternative constructed conceptions. Thus, the literature discusses (a) concept replacement (e.g., Posner et al. 1982), (b) conception development (e.g., Duit et al. 2012), and (c) an awareness of the difference between alternative conceptions and scientific norms as well as their context-specific appropriate applications (e.g., development of metacognitive skills: González Galli et al. 2020; comparison of everyday language and technical language: Sinatra et al. 2008).

Teaching evolution means addressing the relationship between student conceptions and curricular and content-related requirements

In evolution lessons, teachers need to consider both heterogeneous student conceptions and scientific norms. Moreover, teachers should relate these aspects when planning and conducting lessons. In science education, different approaches have been developed to address this relationship, e.g., the model of educational reconstruction (Duit et al. 2012). In some approaches (e.g., Duit et al. 2012 p 24), student conceptions and scientific norms "are regarded as equally important for designing instruction". With reference to the theoretical background and terminology of Helsper (1996) and Bonnet (2020), we describe this relation between an orientation to the requirements of the learning matter and that to the person of the learner as systematic and constitutive antinomy (*Sachantinomie*). The term antinomy is used to describe indissoluble tensions whose respective opposing expectations and target perspectives are to be strived for, but which, because their nature is fundamentally contradictory, both cannot simultaneously guide the teachers' actions in a specific situation. From this perspective, the requirements, challenges, and problems can be focussed upon that are inherent in the structure of institutional action that teachers must address. When addressing student conceptions, teachers are faced with decision-making situations in which they cannot meet all normative expectations equally due to limited time and attention. On the one hand, they are expected to consider the individual peculiarities of each learner when designing teaching–learning processes (e.g., student conceptions and everyday language). On the other hand, curricular and content-related requirements, which apply equally to all students and are assessed via a joint exam, must be enforced within a certain period (e.g., scientific norms and technical language). When teaching evolution, teachers must decide after every student statement how to address it: On the one hand, their actions can aim to ensure that students can adequately apply the synthetic theory of evolution in their statements about an evolutionary biological phenomenon, e.g., by asking the students to express themselves accordingly. On the other

hand, their actions can aim to understand how the students think about evolution by looking more closely at their statements and the suspected diverse conceptions that lie behind them. One could discuss the extent to which scientifically inadequate and/or adequate teleologies (Trommler and Hammann 2020) can be found in the statements. Since student conceptions about evolution are heterogeneous, teachers' actions are likely structured by contradictory expectations, even when they are oriented to the person of the learner. On the one hand, individual concepts should be considered; on the other hand, a shared teaching–learning process should occur in which not all concepts can become equally significant simultaneously. One general reason is that the standardised, rule-governed school system strives for selection and homogenisation. At the same time, the educational goal of teachers includes promoting all students in their uniqueness.

We believe that addressing this antinomy (*Sachantinomie)* is crucial, as it decisively structures the subject-specific teaching, learning and educational processes and (in particular) the addressing of student conceptions. For evolution education, the teachers' actions in addressing student conceptions should not be one-sidedly oriented to the requirements of the learning matter (e.g., scientific norms and technical language) because student learning threatens to fail, as the learning matter may not be connectable to their experiences and knowledge. If, on the other hand, the teacher orients one-sidedly towards the person of the learner (e.g., student conceptions and everyday language), the objective factual logic is in danger of being lost, which also would not be in line with educational policy requirements. According to Helsper's (1996) structural-theoretical approach, professionalism is demonstrated by the ability to manage antinomy appropriately. Teachers should recognise its indissolubility, endure it, and make well-founded decisions for their actions while weighing alternative courses of action. From our perspective, both the student conceptions and the curricular and content-related requirements of the learning matter should therefore play equal roles in *larger* teaching contexts (e.g., when planning and implementing a series of lessons). For a person orientation to become significant, devaluing student conceptions as misconceptions and learning problems seems untenable. If we are concerned about student intellectual growth and development, these student-related matters should also shape the way we frame and conceptualise our approaches for addressing student conceptions. At the same time, we consider the claim that student conceptions should be used comprehensively for individualised learning to be an unrealisable ideal due to structural and systemic problems that prevent practical realisation. Teachers can practice addressing student conceptions in quite different ways. Thereby, they can strive for different goals, depending on the teaching situation and the student conceptions. Thus, teachers can aspire to the goals discussed in evolution education: (a) replacement of Lamarckian explanations of heredity by more appropriate explanations; (b) development of more elaborate explanations of adaptation; and (c) awareness that, in addition to a personal relationship with nature, an objective approach is also useful, and worth being considered. Thus, in the discussion about a professional way of addressing student conceptions and their perceptions in teacher education distinguishing between *good* and *effective* teaching is useful. We follow the assumption of Berliner (1987, p 94) that "(the) concept of good teaching always requires an understanding of normative behaviour, while the concept of effective teaching always requires an understanding of the expected outcomes of instruction." As teachers are confronted with different obligations and goals in the classroom, compromises are always necessary due to limited time (Shulman 1987). Therefore, we argue that the concept of good teaching is also useful for the discussion about a professional way of addressing student conceptions. As the remarks on antinomy should make clear, a crucial question in addressing student conceptions is how it *should be*. Faced with the question of whether to address student conceptions *effectively* or *well*, we believe that evolution education cannot take either side. Rather, to address its tasks, it should try to do both in an enlightened way. A *good way* of addressing student conceptions, which can be characterised by an appreciative perspective of them, may not necessarily be an *effective way* of handling them, as the expected outcomes can also be missed (e.g., a conceptual development). Antinomy (*Sachantinomie*) can be used as a heuristic to discuss what constitutes a good way of addressing student conceptions. The question of the appropriateness or quality of these claims remains an ongoing cause for reflection because a significant challenge is coming to grips with what students understand and how to move them forward in terms of content knowledge alone. Thus, student conceptions have changed to a certain extent, but that should not be the only criteria for the evaluation of addressing student conceptions. Therefore, in addition to the product quality of teaching, the process quality

also becomes significant. An important question is how to design effective teaching–learning processes to make as many desired goals attainable for as many students as possible in the time and resources available. However, in the discussions on effectively addressing student conceptions, teachers' professionalism risks being undermined when (descriptive) research results are used to prescribe how teachers should address student conceptions and the goals they must achieve in doing so. In line with Shulman (1986), who assumes an indeterminacy of rules, one reason is that the case specificity of teaching allows general rules only to a limited extent and requires professional decisions. Regarding teacher education, the concepts for effectively addressing student conceptions used in evolution education often implicitly contain normative assumptions that are more general about teaching, learning, and its goals. Here, the various theories of conceptual change contradict each other (Duit and Widodo 2013).

Scholars such as Schön (1983) and Neuweg (2004) argue that teaching is often guided by tacit knowledge. In his 1983 book, *The Reflective Practitioner: How Professionals Think in Action*, Schön addresses not only the analysis of the distinctive structure of reflection-in-action but also the distinctive structure of professionalised action. He assumes that, although many actions may be the result of a deliberate planning process, routines and international patterns are based on tacit knowledge. The competent practitioner "makes innumerable judgements of quality for which he cannot state adequate criteria, and he displays skills for which he cannot state the rules and procedures" (Schön 1983, p 50). Schön (1983, p 39–40) argues that the distinctive structure of professionalised action cannot be sufficiently described with the model of Technical Rationality and with a purpose-oriented theory of action because practice is not solely a purpose–rational and intentional construct. Like Schön (1983), the distinction between explicit and tacit knowledge is often made by reference to Polanyi's concept of tacit knowledge (Polanyi 1966). Polanyi conceptualises the notion of tacit knowledge from a philosophical and psychological perspective in relation to an individual's actions. He assumes, for instance, that we are not able to fully explain and fully verbalise our actions. Schön's concept of reflection-in-action is essential for practitioners' becoming aware of their tacit frames, e.g., reflecting upon the way in the problem is framed. Shulman addresses the ideas of Schön (1983), and one of the conclusions is that teacher educators need to make teachers' tacit knowledge explicit to become better educators (Shulman 1988). Especially for the teaching profession, Neuweg (2004) elaborated the teaching–learning significance of Polanyi's theory of cognition and knowledge. In science education, several scholars have also assumed that tacit knowledge is significant for better understanding teaching and learning (e.g., Gresch and Martens 2019; Brock 2017; Glass 2013; Taber 2014). For the present study, the research project of Gresch and Martens (2019), which empirically reconstructs the tacit knowledge that structures the way teachers address student conceptions in the classroom, is relevant. They analysed interactions in evolution lessons and reconstructed two types of teachers who address teleology in two different ways. In one, "the teachers combine intentional and need-based teleological explanations with aspects of scientific theories in an ambiguous way". The other type of teachers "construct a duality between correct mechanistic and incorrect teleological explanations by discrediting preceding scientific theories" (Gresch and Martens 2019, p 1). The reconstruction of the classroom interactions reveals a tension between scientific norms and student conceptions, so these empirical findings can be connected to the theoretical considerations of antinomy (*Sachantinomie)*.

Teaching evolution requires a professional vision

Consensus is widespread in the evolution education research that diagnosing and addressing well-known student alternative conceptions is particularly important for teaching evolution effectively (e.g., Hartelt et al. 2022; Ziadie and Andrews 2018). As classrooms are complex environments with many actions occurring simultaneously and a wide range of issues emerging, teachers must choose where to direct attention and which situations to interpret. Scholars such as Berliner (1994) and Schoenfeld (2011) argue that a key component of teaching expertise is the ability to recognise and interpret the occurrences in one's classroom. Schoenfeld (2011, p 228) highlights the importance of teacher noticing by assuming that "what you see and don't see shapes what you do and don't do." To describe and explore this ability of preservice and in-service teachers, the concept can be used of professional vision by anthropologist Goodwin (1994). This concept has been adopted in educational research, especially in the research of mathematics teacher noticing. Noticing and interpreting situations relevant to student thinking, e.g., carefully listening to what students actually say while neglecting other things happening

in the classroom, is not a simple matter. The important question is *how* teachers perceive student conceptions, as this question influences *how* they address them in the classroom. One evidence-based reason is that few findings have been made on the importance of professional vision for teaching practice. Some studies have demonstrated that a change in the way lesson videos are viewed also means a change in professional vision during teaching (e.g., Kersting et al. 2012; van Es and Sherin 2010; Sherin 2007). Here, the research project of van Es and Sherin (2010) is of particular interest. It addresses the influence of teachers' professional vision on teachers' thinking and teaching. They analysed the professional vision of seven fourth- and fifth-grade teachers from an urban school, which met once or twice a month for 10 video-club session, in which they watched and discussed video excerpts from their classrooms. The video club was "designed to help teachers learn to notice the particulars of student mathematical thinking" (Kersting et al. 2012, p 159). One result was that participating teachers paid closer attention to student ideas while teaching, e.g., they "provided more opportunities for students to express their thinking and explore mathematical ideas, and they probed student thinking in substantive ways" (van Es and Sherin 2010, p 172).

Despite frequent reference to Goodwin (1994), different conceptualisations and perspectives on professional vision can be observed in theoretical and empirical studies in the context of teacher education (Dindyal et al. 2021; Santagata et al. 2021). Many studies on noticing have focussed on it as a cognitive and mental process conducted by an individual teacher. In these approaches, teacher noticing is conceived as a psychological construct, which is conceptualised from the perspective of a purpose-oriented theory of action. In this sense, professional vision is a purpose–rational and intentional construct, so a rational actor is assumed who purposefully uses professional knowledge for noticing. One influential conceptualisation comes from Sherin (2007), who summarised teachers' professional vision as the ability and the use of professional knowledge by a teacher to notice (selective attention) and interpret (knowledge-based reasoning) significant learning-relevant events in the complexity of a classroom interaction. In addition to structural models of professional vision, process models are discussed in the relevant literature (e.g., Blömeke et al. 2015). Noticing is often examined with methods of competence research, e.g., with standardised video-based tests that use task prompts. Professional competence is thereby operationalised as the conformity of coding with an expert norm. These studies have focussed on individual teachers and their knowledge, which is a priori scientifically categorised and evaluated, for example, as content and pedagogical content knowledge. Such studies have empirically proven, among other things, which professional knowledge correlates with noticing (e.g., Kramer et al. 2021) and that this ability develops as expertise grows (e.g., Gegenfurtner et al. 2020). In most studies, expert teachers are better able to notice than are novice teachers (Gegenfurtner et al. 2020). The state of the research varies depending on the teaching aspect considered. Biology-specific aspects have only been investigated in a few studies (e.g., Kramer et al. 2021). To our knowledge, *how* preservice and in-service teachers perceive student conceptions in the evolution classroom has not yet been explored.

In line with Goodwin (1994), we adopt a sociocultural perspective on the construct of professional vision. This approach allows us to contribute to the current state of research on professional vision, as it enables us to explore the social dimension of professional vision. In our view, this ability is necessary to obtain a comprehensive view of the phenomena. Goodwin (1994, p 606), referring to Bourdieu (1977), starts from a "practice-based theory of knowledge and action" and characterises professional vision as "socially organized ways of seeing and understanding events" that become significant in social contexts. In this sense, "the ability to see relevant entities is lodged not in the individual mind but instead within a community of competent practitioners" (Bourdieu 1977, p 626). A basic reasoning in a theory of social practices such as Bourdieu's (1977) is that structures established within a cultural context shape the way in which those who live in that context think and act. Thinking and acting are intrinsically connected with perceptive skills so the structures shape the ability to perceive (Reckwitz 2002). Based on his analyses, Goodwin (1994, p 606) assumes that each profession has its own practice to see and argues that "(all) vision is perspectival and lodged within endogenous communities of practice." In line with a sociocultural perspective on noticing (e.g., Scheiner 2021; Louie 2018), we follow Goodwin's (1994) sociological perspective on vision and focus on *how* vision is socially organised. We assume that this perspective is appropriate for the conceptualisation of professional vision for the profession of teachers and is important

in the context of teacher education. One major reason is that preservice and in-service teachers' professional vision is expressed in social contexts, where access to professionalisation is offered. This is especially the case when teachers repeatedly see and talk about (other people's) lessons, e.g., in the context of video observations and classroom debriefings in practice phases during studies, in the teacher traineeship or during peer teaching observations. Accordingly, professional vision becomes significant from the perspective of teacher education whenever interactions between different people can be observed. This argument is connectable to Goodwin (1994), who emphasises the linguistic aspect of professional vision and examines the speaking of professionals. Some studies are available on speaking about teaching in a social context. Sherin's research group, which first applied the concept of professional vision to the teaching profession in the early 2000s, investigated teachers' talk about mathematics lessons in the context of professional development programmes, so-called video clubs (e.g., van Es and Sherin 2010). We applied the perspective of a theory of social practices (Reckwitz 2002) to our research objective. In doing so, we recognise that, when executing a professional vision, tacit knowledge has an action-guiding effect, which is not necessarily subject to an intentional and purposive logic. Preservice and in-service biology teachers repeatedly see and talk about lessons. Therefore, we assume, with reference to Mannheim (1982) and Bohnsack (2010), that tacit knowledge is generated in social interactions within a certain community. In social interaction, members of a community who share experiential spaces such as a profession can interact and understand each other immediately. Consequently, this knowledge does not need to be explicated because understanding can be taken for granted. The origin of this understanding is a common history of socialisation and common or similar experiences (Bohnsack 2021). Thus, professional vision does not exclusively follow individual knowledge and ability but is influenced by sociocultural patterns of perception. We methodically capture tacit knowledge as frameworks of orientation (Bohnsack 2010), originating from collective social experiences. From our perspective, the phrase "framework of orientation" can be related to other terms and concepts: "perspectival framework" (Goodwin 1994, p 622) or "tacit frames" (Schön 1983, p 311). The object of vision, whom or what I look at, and especially the way I present myself to other people in this social practice, is influenced by the profession-related experiences one has made. Teachers attribute an implicitly known and collectively shared importance to the phenomena (e.g., student alternative conceptions) they see and talk about. The theory of practice emphasises that tacit knowledge toned not correspond to explicitly expressed knowledge (Reckwitz 2002). In the evolution education research, the explicitly expressed norms regarding the addressing student conceptions contradict the teaching practice and tacit routines (Gresch 2020).

Conceptualisation as a social practice enables a contribution to the research, as the tacit knowledge and the social dimension of professional vision can be investigated, which are largely unexplored. We are aware of only one qualitative-reconstructive case study from sports didactics that investigates teachers' tacit knowledge of professional vision (Schiller 2019).

Research question

In evolution lessons, students use teleological and anthropomorphic conceptions to explain evolutionary biological phenomena. For preservice and in-service teachers to address these student conceptions professionally, they must develop an appropriate professional vision. To develop teacher education courses, the current state must first be described and better understood, especially how professional vision is practised and performed. The central research question is as follows: *How* do preservice and in-service biology teachers talk about addressing student conceptions in an evolution lesson, and what tacit knowledge guides their actions?

Methodical approach

Video clip construction

In line with many studies, we used a video clip to provide a basis for professional vision since lesson videos enable an authentic representation of complex classroom settings. In the study context, 51 evolution lessons (45 or 60 min.) in lower and upper secondary schools were video- and audiotaped. Based on this material, several video clips were created that show classroom interactions between students and teachers, especially regarding addressing anthropomorphic and teleological explanations. For the data collection, we selected a video clip (advanced course, vocational college, duration: 20 min.) that proved particularly suitable in the context of joint analyses with preservice biology teachers. The focus of the lesson is the evolutionary adaptation of

species to their habitat, which is addressed in different contexts, including the causes of bird migration and the phylogenetic development of the burrowing mole.

To obtain an idea of what happens in this video clip, the reconstruction results of another study by Gresch and Martens (2019) are briefly summarised. The teacher problematises the complex scientific content through the construction of an unambiguous duality and incompatibility of scientific explanations and teleology. The interactions can reconstruct situations in which the teacher constructs a difference by contrasting the synthetic theory of evolution, which is introduced as scientifically correct, with the student conceptions, especially final and teleological thinking, as well as Lamarck's theory of evolution, which are presented as wrong. Student conceptions and scientific norms are contrasted as two opposing explanatory types for the trait evolutions. This polarisation can be reconstructed since all student statements observable in the video clip are classified into the categories "right" or "wrong". The students in the video clip take up this polarisation, discuss the issue of teleology critically, and reject teleological explanations. The normative background that is implicitly proposed is that explanations must be scientific. By equating student conceptions with Lamarck's scientific theory of evolution and intentional thinking, student conceptions about evolutionary adaptation appear as conscious decision-making processes. At the same time, Lamarck's theory of evolution is discredited as an everyday conception. The teacher evaluates the student conceptions as stable and obstructive in terms of learning.

Data collection: group discussions and individual interviews

The video clip, which also includes contextual information (e.g., work material used in class), serves as a stimulus for group discussions (Bohnsack 2010) and (due to the COVID pandemic) individual interviews (Nohl 2010). After watching this video clip, preservice and in-service biology teachers were invited to talk about what they saw without any further specific instructions to assure the openness of the research approach. The aim is to ensure that the participants can express their own structures of importance from which the tacit knowledge can be reconstructed (Bohnsack 2010). Following Nohl (2017), we assume that group discussion and individual interviews can be triangulated since both methods of data collection frameworks of orientation are addressed.

Sample

Our empirical basis comprises 115 preservice and in-service biology teachers who participated in 31 group discussions (average duration: 45 min.) and 9 individual interviews (average duration: 25 min.). Participation was voluntary and took place independently of educational contexts in a room chosen by the participants (e.g., classroom). Real social groups of 3–4 persons participated in the group discussion (e.g., befriended preservice teachers or teachers working together at the same school). Initially, the intention was only to investigate the professional vision of preservice teachers. Early in the research process, the sampling strategy was changed to also allow for maximally contrasting case comparisons. Therefore, both trainee teachers and (experienced) in-service teachers were included in the sample. A group discussion and an individual interview each represent a case.

To enable efficient comparative analyses and to saturate the sample sufficiently, the cases were selected stepwise according to the principle of maximum contrast in the sense of theoretical sampling (Glaser and Strauss 2009). This principle means that the selection of further cases was based on empirical reconstructions already conducted so the sample was formed continually during the research process. After the initial case comparisons and considerations for typification, to increase our sample variance, we conducted a theory-driven search for additional contrasting cases. To increase the sample variance, we attempted to contact teachers who were more student-centred in their professional vision than were those in previous cases. Cases were studied in which an orientation was to be expected towards individual students in the professional vision (e.g., teachers from schools with individualisation concepts). In general, the participants had different personal and professional backgrounds: (a) 79 preservice biology teachers, aged 20–35 years and from different universities who are studying for a bachelor's or master's degree in different target school types (primary, lower secondary, secondary, grammar, and comprehensive school as well as vocational college); (b) 18 trainee teachers aged 23–30 years and (c) 18 in-service teachers from different school types with varying degrees of teaching experience (3–29 years).

Data analysis: documentary method

The transcribed conversations about the lessons were interpreted using the documentary method (Bohnsack 2010). This method is geared towards the analysis of social practices and, due to its sociological foundation, enables a differentiation between explicit and tacit knowledge in separate analytical steps. The central methodological foundation is the change in analytic stance from asking about the *what* to the *how* of social practice, which can be seen as the core of many reconstructive research methods. Such a distinction allows methodologically controlled access to tacit knowledge, which, in everyday life, usually defies explication. The documentary

method distinguishes and systematically relates the immanent (explicit and literal) meaning of *what* is said and done as well as the documentary (tacit) meaning, or *how* something is said and done. To elaborate the explicit knowledge, we analysed the norms and common-sense theories (Bohnsack 2010) associated with professional vision as a goal-directed process that teachers notice and explicate. Revealing the underlying implicit meaning requires going beyond the literal. We conducted the following steps (Bohnsack 2010, 2021): (1) Transcribe the group discussions and individual interviews according to the guidelines from "Talk in Qualitative Social Research", which is commonly used for documentary interpretation (Przyborski and Wohlrab-Sahr 2014, p 167–169). (2) Identify the sections in which the participants talk about student conceptions and how to address them. Identify sections according to the criteria typical for the documentary method, which are considered to reveal the agents' underlying orientation frameworks (e.g., the entrance passage or passages with metaphoric and interactive density). (3) Reformulate the immanent (explicit and literal) meaning of *what* is said (structuring through main topics and subordinate topics). (4) Reconstruct the documentary (tacit) meaning of *how* something is said by means of case comparisons. By asking how teachers of comparable cases talk about the video clip, the practice of professional vision and the associated action-guiding tacit knowledge of the case become clear and thus particularly accessible to reconstruction. We were guided by questions such as the following: What is assumed, imputed, and concealed when talking about the evolution lesson? Against the background of which orientation framework does a particular professional vision make sense? (5) Generalise through a typification: The generalisation begins with the development of a base type that describes the orientations that *all* cases have in common. For example, a goal in addressing student conceptions is implicitly assumed in all cases. Through case comparisons, we determined that the goal orientation was enacted in different ways. Elaborating the contrasts in the commonalities led to the development of ideal types, each describing an alternative practice of professional vision. Case-internal and cross-case comparative analyses are significant because only through comparison can the structural differences and similarities between the orientation frameworks be revealed. The base type and the ideal types represent an "analytic generalisation" (Firestone 1993, p 16), since we reconstructed orientations that are of general importance. The case-specific findings were formulated more abstractly in the context of typification, so the specific features of each case were abstracted.

Of the 40 available cases, characterised by variance and allow for minimum and maximum contrasts, 15 were fully interpreted and used for typification (12 group discussions: 1 group of in-service teachers, 3 groups of trainee teachers and 8 groups of preservice biology teachers) and 3 individual interviews with in-service teachers). For anonymity, all cases were labelled with fruit names (e.g., rosehip) that reveal nothing about the content. In the sense of theoretical saturation (Glaser and Strauss 2009), our analyses of the opening passage and other transcript passages relevant to the research question for the remaining 25 cases did not lead to any new insights into previously reconstructed orientations or could no longer contribute to the analytical differentiation, so they were not fully interpreted. Our sampling strategy enabled us to repeatedly collect cases that allowed us to reconstruct new orientations. The sampling and analyses were terminated when, after searching for more cases that suggested contrasts, we were able only to reconstruct repetitive orientations.

The standards of reconstructive social research require us to question whether the interpretations are adequate and to reflect upon the perspective and potential normative bias of the researcher. Thus, exemplary interpretations (all of those presented in this article) were discussed in groups of researchers who are familiar with the methodological background. In addition, the discussions of case comparisons are especially important because they allow a methodological control of the perspective and potential normative bias of the researcher within a certain range. Empirical comparative horizons are brought to the empirical cases instead of a personal, implicit comparative horizon (Bohnsack 2021).

Results: professional vision practices

Base type

The step of typification starts with the development of a base type by looking for tacit knowledge that can be reconstructed in all cases. In all cases, when talking about addressing student conceptions in the evolution lesson, two key issues could be reconstructed: (1) the relation of teaching and learning scientific norms and (2) the relation of student conceptions and scientific norms. These

two key issues were consistently processed in the mode of an evaluation. The preservice and in-service biology teachers position themselves as persons who can evaluate the teacher and the students, and for this purpose, they bring norms (e.g., fixed behavioural criteria) to the classroom. They construct a contrast between the situations seen in the lesson video and other (hypothetical or real) courses of action as well as between what the teacher and students did and what they should have done. Thereby, an orientation towards unambiguity is evident, so that the evaluations are constructed as unquestionably valid. Student statements are classified under categories of student conceptions and/or under the categories "right" and "wrong", so a subsumptive–generalising attitude of observation is adopted. In all cases, an orientation can be reconstructed towards homogenisation and optimisation: Teaching aims at learning scientific norms, which is assumed similar for all students, whereby teaching and learning are constructed as something that should be improved.

After comparative analyses were used to reconstruct commonalities of all cases, we also looked for differences in the way these two issues are addressed in doing professional vision. These two key issues can be considered two main dimensions of comparison and used for typification. In doing so, we were guided by the question of how the different cases address these two issues in concrete terms, i.e., which frameworks of orientation guide the teachers in enacting a professional vision. This paper presents the typology regarding the key issue, the relation of student conceptions and scientific norms.[1] This typology should also be published elsewhere (Steinwachs and Martens, submitted). However, in this paper, we present two new sample cases as well as other and more extensive transcript passages that provide new and deeper insights.

Typology: relation of student conceptions and scientific norms

From a methodological perspective (Bohnsack 2021), the cross-case orientations of the base type represent empirically generated comparative dimensions. With these dimensions, contrasts within the cases of our sample can be described, and the ideal–typical can be elaborated. Four ideal types were formed, indicating different social practices of professional vision. The following contoured presentation is based on transcript excerpts from four cases, where one case is used to illustrate each ideal type. The presentations do not follow the course of the conversation but begin by illustrating aspects of the base type. The descriptions are then structured according to three reconstructed dimensions of comparison, which concretise the main comparison dimension and are significant when performing professional vision: (1) How are student conceptions and scientific norms related? (2) What goal is constructed in terms of addressing student conceptions? (3) What importance is attributed to student conceptions for teaching and learning scientific norms? How these three comparative dimensions are processed differs between the cases studied. We developed four ideal types, which form a typology. The naming of the ideal types is based on the differently constructed goals in addressing student conceptions, as this is a particularly suitable way of illustrating the differences.

Regarding the results presentation, the orientations illustrated in the cases are also homologous in other transcript passages of the same case and in other cases of the associated type. The presentations serve to illustrate the condensed interpretations based on extensive comparative analyses (within and across cases) that cannot be presented here. The German transcripts are the basis of all the interpretations and were then translated. According to Przyborski and Wohlrab-Sahr (2014), translation produces ambiguities and questions about the connotations of certain utterances are raised in following interpretations, which can only be answered by referring to the original German transcripts. Due to the translation, the original wording and especially its meaning cannot be exactly reproduced. In addition, the transcription rules[2] used should be considered (see footnote 2).

Type 1: complete acquisition of scientific norms by filling gaps in subject-specific knowledge and correcting incorrect knowledge

The rosehip group consisted of three teachers from a comprehensive school (3–5 years of teaching experience). The following three transcript excerpts are part of an extensive passage in which the teachers talked about how to formulate explanations for trait evolution. The teachers also discussed how to address student statements and the extent to which the teacher in the lesson video did so.

[1] Typology on the main comparative dimension of the relation of teaching and appropriation shall be published elsewhere: Steinwachs and Martens (in preparation).

[2] Transcription rules, according to Przyborski and Wohlrab-Sahr (2014): All participants are assigned a letter for anonymization. Depending on gender, an "f" (for female) or an "m" (for male) is added to this letter. When all participants comment at the same time, the speaker is referred to as "all". Word is emphasized. °Word° is said quietly. (3) is a pause of three seconds. └is an overlap of two speakers. @Word@ is said laughing. Transcription rules according to Dresing et all (2018, p 21–24): Word blends are approximated to written German. Stuttering is smoothed or omitted. Word duplications are recorded only if they are used as a stylistic device for emphasis. Half-sentences that lack completion are marked with the break-off character "/". Punctuation is smoothed in favour of readability. If direct speech is quoted in the recording, the quotation is placed in quotation marks.

Af: I somehow miss this step all the time, with which/ Recombination happens and then I have different descendants, instead of playing it through like this: I now have different descendants with different characteristics and some are just well adapted to their environment, others are less well adapted. And then some survive, the others do not. Which genes are inherited? The ones that were best ⌊adapted to the environment. (2) Yes.⌋ But it was never gone through
Bm: ⌊Who just have the highest reproductive fitness. Right.⌋
Af: like ⌊that. I miss this step-by-step approach.⌋
Bm: ⌊Nah, it is always/⌋ That is also true, now that you mention it. Here, only mutation is always ⌊assumed⌋ as an evolutionary factor, <u>never</u> recombination actually. Right.

Af: ⌊Yes.⌋ (3) Yeah, but they have always been talking about the germ cells and stuff, which already suggests, ⌊that it/⌋
Bm: ⌊Yes, but⌋ because they say <u>if</u> a change has to take place, a ⌊mutation⌋ has to take place as a change ⌊then in the germ cells.⌋ So the
Af: ⌊Yes.⌋ ⌊Then in the germ cells, yes.⌋
Bm: mutation/ but that in principle recombination is ultimately ⌊also possible, (2)⌋ the evolutionary factor of
Af: ⌊Possible. Does not come at all, that is right.⌋
Bm: recombination is actually/ is not discussed at all.
Af: Yes, and I really think that you should actually take an example and play through it like I said and then classify <u>all</u> these terms. So you could ⌊take⌋ the mole for example and say: what about the evolution of the mole, and these
Bm: ⌊Mhm⌋
Af: digging hands or whatever, these shovels for digging? And then you could play through that, and then you could insert all these aspects, that not only mutation but also recombination plays a role for the descendants and so on. Or you could have played through the white gorilla blah, with the white and black gorilla and which one survives. They always hinted at it in a way, but I always missed the right technical terms and a clear structure every time you go through it.

[…]

Af: That is another point, she said 'yes', or 'mhm'. And then let it go on, because it was actually wrong, and then waited until someone said it <u>correctly</u>, and then said 'that is exactly how it should be', but she did not correct the children who had said something truly <u>wrong</u> in that context. I think that when it comes to such important concepts, one should intervene when someone says, I do not know, 'the mole can dig better because he has practiced, and then he passes that on to his children'. That is ⌊problematic⌋ then. Isn't it.
Bm: ⌊Yes.⌋

[…]

Bm: Let me put it this way, with the white gorilla one could at least/ ⌊(3) It is clear to everyone that he is probably not consciously turning white.⌋
Af: ⌊Yes, or you take/ (2) Nope exactly.⌋ But there it came again/ Again, someone said it is in the skin cells and I was like, 'huh'? The white is now in the skin cells? Did he put that in there? That is what it sounded like. So one of them said something like, 'the white goes into the skin cells' or something like that. In any case, very strange. I think why not take a super clear example where you cannot go wrong, like the one with the butterfly that then in industrialization/ ⌊The⌋ trees turn black, the butterfly turns
Cf: ⌊Yes yes.⌋
Af: ⌊black⌋ . Exactly, that is what it is called. Why not take an example like that, you really cannot do much ⌊wrong⌋ .
Bm: ⌊Industrial melanism.⌋
Cf: ⌊Yes.⌋
Af: There is also not so much like 'the butterfly wanted to turn black' or whatever. ⌊I think that could be much better/ (2)⌋ exactly, then you can still say 'it is wrong'.
Cf: ⌊Yes, and when that comes, you can always intervene.⌋

(Transcript: l.144-172; l.241-248; l.360-375)

In accordance with the base type, the teachers position themselves as a person who can evaluate the teacher and the students. Learning scientific norms is constructed as unsuccessful ("I always missed the right technical terms"), and the inadequate teaching is constructed as the cause ("I miss this step-by-step approach"). The participants' assessments are guided by homogenisation, which becomes evident by constructing the diverse students as one group and by making broad inferences about all students from individual observations in the video clip ("they say" and "they have"). The manner of assessment also reveals the norms that the participants bring to the classroom and use to evaluate the lesson. The participants construct contrasts between the situations seen in the evolution lesson and a hypothetical course of action as well as between what the teachers and students

did and what they should have done. The construction of this contrast shows that a different way of teaching is demanded and thus an orientation towards optimisation can be illustrated. In the evaluation mode, the participants are oriented towards unambiguity so the evaluations are constructed as unquestionably valid ("I always missed the right technical terms and a clear structure every time"). The student statements are classified under categories such as "right" and "wrong", so a subsumptive–generalising attitude of observation is adopted ("the right technical terms", "wrong", "truly wrong", and "said it correctly").

Regarding the first dimension of comparison, i.e., the way of relating student conceptions and scientific norms, a dichotomous relation can be reconstructed in the rosehip case. This relation can be illustrated through the construction of a contrast, according to which the student conceptions are regarded as wrong and scientific norms are regarded as right. Thus, student conceptions and scientific norms are contrasted as two opposing types of explanations for the evolution of traits. In doing so, student conceptions are constructed from a deficit perspective as a knowledge of delimitation. They are negotiated as false knowledge that is constructed in distinction to the scientific norm. In contrast, student conceptions in the maracuja case (Type 4) are seen as a part of the students, and they are conceptualised as something experiential and inevitable. Consequently, they are precisely not regarded as something that can only be understood against the comparative horizon of the scientific norm.

Regarding the second comparative dimension, i.e., the goal in addressing student conceptions, the complete acquirement of scientific norms by filling gaps in subject-specific knowledge and correcting incorrect knowledge can be reconstructed in the rosehip case. The correction of incorrect knowledge can be illustrated by the use of different statements and metaphors, according to which the teacher is supposed to check the scientific correctness and correct the student statements ("she did not correct the children who had said something truly wrong ", "intervene", and "then you can still say 'it is wrong'"). The filling of gaps in subject-specific knowledge can be reconstructed in other transcript passages. In these, the participants analyse and interpret the student statements as still missing some aspects constructed as mandatory. Thus, the students do not yet explain evolution in a completely correct way ("the evolutionary factor of recombination is actually/ is not discussed at all" and "missed the right technical terms ").

Regarding the third dimension of comparison, i.e., the importance of student conceptions for teaching and learning scientific norms, student conceptions are seen as indicators of missing and incorrect knowledge in the case of rosehip. This problem can be illustrated by the fact that teachers are oriented in their vision to identify errors and misunderstandings in student statements. They analyse what students do not know yet and what is missing in their explanation for the trait evolution. Student conceptions are constructed as significant to the teaching activities because they indicate the extent to which students use scientific norms to explain trait evolution in the classroom. This process then serves the teachers as they discuss how to close the gap between student knowledge and scientific norms. At the centre of teaching and learning, however, are scientific norms. This centrality can be illustrated by the fact that the conditions for successful teaching and learning are primarily linked to the scientific norms. The order of evolutionary factors when explaining evolution ("step-by-step approach"), their completeness ("classify all these terms") and correctness ("the right technical terms") are constructed as conditions for successful teaching and learning. On the other hand, if the required way of teaching is followed, learning scientific norms is constructed as not very challenging. This situation can be illustrated by the use of metaphors such as "classify" and "insert", according to which learning the norm is understood as a simple activity. Consistent with this understanding, the selection of the content examples of evolution used in the classroom can control the student understanding of scientific norms. The student conceptions or their own explanations of evolution are not seen here, in contrast to other types, as something that is significant for teaching and/or learning since examples are to be used where they do not occur in the first place ("I think why not take a super clear example where you cannot go wrong").

Type 2: removing and replacing student conceptions with scientific norms

The pineapple group consists of four students studying biology in the Master of Education program at the same university. The content of the three transcript excerpts is part of an extensive passage in which the students talk about how student conceptions are addressed in the evolution lessons they have seen and how they should have been addressed.

Af: About the antibiotic resistance, I think, it is also a conception that the body reacts to it, and not the bacteria. And that this was not present as a problem. Somehow, she did not highlight a problem. Like 'ok, that is now/ So can it work like that? And let us somehow think about it more carefully, because that somehow/' So this conception is still in them. They understand that it works somehow with selection and somehow with mutation, but I think they still have not understood how it truly works. […] So I think that is why you survey these students' conceptions, somehow. You look at them in order to see, in a way, what kind of problem there actually is? So why can this not work? […]

Af: But I think the problem is that they say it so quickly and you cannot pick it up as quickly ⌊yourself, right?⌋

Bf: ⌊Yes, yes definitely,⌋ yes. (3) But then I think that especially when the students say so much, she should somehow put out the core statements so that it is ⌊clear⌋ to everyone what is the ⌊right thing to say and what I⌋ have to remember now.

Af: ⌊Mhm⌋

Cf: ⌊(Indeed. ⌊Right, exactly.⌋ Mhm.)⌋

Af: ⌊That is right.⌋

Af: Yes. (6)

Dm: Yes, so if we here at the very beginning simply/ The first answer is from Lara here apparently, that just the human body adapts/ becomes resistant to the antibiotic, right? And then she also says directly, 'we will keep that in mind'. So at this point I think the teacher already has the intention that they discuss it together ⌊and take up the problem.⌋

Af ⌊Yes, I had also thought that that would be the case. Yes.⌋

Dm: And then she continues to collect the students' answers and every now and then a new disturbing factor comes in. Someone starts saying 'viruses or bacteria'? ⌊Then she has to clear it out first.⌋ And then there comes another one

All: ⌊@(3) Right.@⌋

Dm and says something about surface recognition. ⌊And⌋ I think that maybe she just missed this first problem, which came up directly, a little bit.

Af: ⌊Yes, like immune system.⌋

[…]

Dm: At the end of the lesson a pupil actually said again, 'yes the individual adapts so that it is good', and that is actually exactly what we @did not ⌊want to hear⌋ @ at that point. (3) And then this Johann says, I think that was/ Was that

Af: ⌊Right.⌋

Dm: the one in the back row who always lifted his finger? ⌊(2)⌋ Yes, exactly. He now gives again/ drops selection again

Af: ⌊°He has summarized everything again, hasn't he?°⌋

Dm: somehow, the term, and then the teacher says 'exactly'. That is more or less it, isn't it? (12)

Bf: At the end the teacher talks quite a lot again, but I think she only says, how it is not and ⌊where the error in reasoning⌋ lies with Lamarck. But she does not say how it is correct.

Cf: ⌊Mhm, exactly.⌋

[…]

Af: Yes, it seems somehow as if Hannah still had in her head: yes, the individuals just adapt in terms of behavior, or whatever. Something just happens with them. But I think she has not quite understood yet that with that/ So because Johann explains it correctly, doesn't he? That it then comes to selection advantages, but I do not think that is at all clear to Hannah. So she just thinks okay, it is an individual which just somehow adapts individually and this individual is just somehow/ So I mean that is how it starts, isn't it. It just has an advantage there, but it is just not so that she understands that this selection advantage is inherited and leads to an adaptation over several generations. So that, I think, is not clear to them/ I do not think it is clear to Hannah.

(Transcript: l.259-308; l.442-467; l.531-541)

According to the base type, the students position themselves as people who can evaluate the teacher and the students. Learning scientific norms is constructed as not very successful ("I think they still have not understood how it truly works"), and inadequate teaching is constructed as the cause ("put out the core statements" and "but she does not say how it is correct"). In the evaluation mode, the participants are oriented towards unambiguity so the evaluations are constructed as unquestionably valid. Student statements are classified under categories such as "right" and "wrong", so a subsumptive–generalising observational attitude is adopted ("right thing", "error in reasoning", or "how it is correct").

Regarding the first dimension of comparison, i.e., the way of relating student conceptions and scientific norms, a dichotomous relation can be reconstructed in the

pineapple case. This situation can be illustrated through the construction of a contrast, according to which student conceptions are regarded as wrong and scientific norms as right. Thus, student conceptions and scientific norms are contrasted as two opposing types of explanations for the evolution of traits. In doing so, student conceptions are constructed from a deficit perspective and in the context of the scientific norm as a "problem". This situation can also be illustrated by the use of metaphors with negative connotations ("disturbing factor" or "error in reasoning"). In contrast, the maracuja case (Type 4) uses metaphors with positive meanings.

Regarding the second comparative dimension, i.e., the goal in addressing student conceptions, in the case of pineapple, the goal is that the student conceptions are removed and replaced by scientific norms. This process can be illustrated by the use of metaphors such as "this conception is still in them", "still had in her head" and "to clear it out". These metaphors indicate that the student conceptions are constructed as something obstructive that is contained in the minds of the students and must be removed before or in the process of teaching scientific norms. In this metaphorical sense, the goal is to get the student conceptions out of the students' mind so that they are free of these conceptions and the teacher can teach scientific norms without hindrance. This objective can also be illustrated by the fact that the orientation towards a complete and equally achievable exchange of conceptions by scientific norms is not irritated for all students. Despite the elaboration and contrasting of the evolution theories, the re-emerging student conceptions are marked as surprising ("still in them" and "they still have not understood how it truly works"). This objective can also be illustrated by the fact that the participants expect the teacher to instruct the students that they should only remember scientifically correct aspects of statements ("what is the right thing to say and what I have to remember"). In contrast, the maracuja case (Type 4) assumes that student conceptions remain present in the students' minds, even though students address scientific norms, and that they use them to explain evolution.

Regarding the third dimension of comparison, i.e., the importance of student conceptions for teaching and learning scientific norms, in the case of pineapple, the student conceptions are understood as a problem and an obstacle for teaching scientific norms. The ideas are constructed as significant from the teacher's perspective, as the teacher is supposed to highlight a "problem" in the student statements. This problem must then be "cleared out" so this "disturbing factor" is no longer there, and scientific norms can be taught.

Type 3: changing student conceptions into scientific norms

The group mirabelle consisted of four trainee teachers who studied at different universities and are now taking part in a biology seminar. In the three transcript excerpts presented, the trainee teachers talk about addressing student conceptions. The first two excerpts are part of the entrance passage. To better understand the third excerpt, the following contextual knowledge about the video clip is useful: Among other things, the teacher asks the students why migratory birds are flying south and gives them the choice of an intentional or a proximate causal answer. The teacher says, "A current phenomenon, migratory birds, they are flying south at the moment. Why do they do that? I'll give you two answers, and you can talk about these answers. Answer A, they want to avoid the cold and lack of food in the winter here. That's why they fly south. Answer B, there is a hormonal change in their body, which is why they experience migratory restlessness and have to escape."

Af: The second part was about this adaptation, └which┘ is always such a sticking point. And I thought that she tried to
Cf: └Mhm.┘
Df: └Yes exactly.┘
Af: somehow evoke an understanding in the students └that┘ goes beyond this everyday understanding and to evoke this
Df: └Mhm.┘
Af: biological/ this evolutionary history. And at that point she also tried └to┘ activate the students' conceptions a little
Cf: └Mhm┘
Af: bit, first of all asking └'where┘ do you know this term from?' What/ a bit of everyday language was └dragged┘ in
Df: └Mhm┘
Cf: └Mhm┘
Af: and then she tried to abstract/ or move away from that to the biological term.
Cf: Mhm, so to bring in the technical language. └Before┘ that the example with the winter jacket and we can adapt,
Af: └Yes, exactly.┘
Cf: actively, and then this/ Mhm, how is it now with/ so at the very end with mutation and everything, adaptation in general/
[…]
Cf: Asking specific questions in class discussion, └guiding┘ questions towards the correct answers. And if the answers
Bm: └Mhm┘
Cf: are then also formulated in technical language as far as possible. So I mean, that is such a staggering of (2) @obstacles that you kind of have to overcome.@ └That┘ is super difficult I think. And then also to think about when to
Bm: └Mhm┘
Cf: interrupt the students, if it is not so technical, in the student answers themselves. How do you make sure that they can truly express/ describe it correctly? (3) Yes. (14)
Df: ○Yes.○
Cf: That is difficult, I think.
Af: I mean, well, the students have in any case already somhow figured out for themselves that the animals cannot think and cannot adapt in a goal-oriented way. So they can already figure it out. (2)
Df: Yes. (4)
Cf: I think it is also a lot about the questioning by the teacher. So I think that was really like ping-pong and in between also a bit ambiguous, somehow, that a lot got mixed up.
[…]
Af: I mean there it became a little bit clear in a way now and └then┘, also with this individual, whether it was
Cf: └Yes┘
Af: purposefully or not, so that, right/ but └that┘ was not an actual query, was it?
Cf: └Yes┘, if at all, with this A and B example again, └is it┘, where one has
Af: └Mhm┘
Cf: noticed that the first pupil has answered └it┘ wrongly, she has/ Wait, answer B was correct, was it, and A was
Df: └Yes┘
Cf: wrong. And she then named answer A and explained that this whole process runs purposefully. Which in the end └is┘ also a students' conceptions because that/ she probably came to class with this knowledge, the class @did not
Df; └Mhm.┘
Cf: contribute significantly@ to her correcting or revising it and then she still went to answering the question with the same knowledge.
(Transcript: l.17-34; l.168-186; l.483-498)

In accordance with the base type, the trainee teachers position themselves as a person who can evaluate the teacher and the students ("a lot got mixed up" and "ambiguous"). Learning scientific norms is constructed as not very successful ("still went to answering the question with the same knowledge"), and inadequate teaching is constructed as the cause ("that the class @did not contribute significantly@"). The multiple use of the verb "tried" reveals an evaluative and deficient view of the lesson, as the teacher's actions are judged to have largely failed despite her efforts. The formulation "in any case" illustrates that the vision is oriented towards a unification, according to which the lesson appears as something that can be seen unambiguously and indisputably. Categories were used to describe the student statements, which indicate that for diagnosis, a subsumptive–generalising observational attitude is adopted ("goal-oriented way").

Regarding the first dimension of comparison, i.e., the way of relating student conceptions and scientific norms, a hierarchical relation can be reconstructed in the mirabelle case. Scientific norms are considered more valuable than are student conceptions. The metaphor "goes beyond this everyday understanding", suggests that student conceptions provide a reference value

for understanding the scientific norm that must be transcended. In a metaphorical sense, scientific norms are above the student conceptions and are to be achieved by the students. The superiority of scientific norms can also be illustrated by the criticism of student statements, according to which they are evaluated in terms of their subject-specificity ("if it is not so technical"). In this critique, the student concepts are constructed as also containing aspects appropriate to scientific norms. In contrast, unlike the pineapple case (Type 2), the mirabelle group uses metaphors with positive connotations for student conceptions ("everyday understanding", "everyday language", and "knowledge"). This fact indicates that they are understood as a way of explaining evolution; however, they are not appropriate overall and should be changed to scientifically appropriate explanations.

Regarding the second comparative dimension, i.e., the goal in addressing student conceptions, a change of student conceptions into scientific norms can be reconstructed in the mirabelle case. This situation can be illustrated by the path and space metaphors used, according to which students metaphorically move from their conceptions towards scientific norms ("goes beyond", "moving away from", and "overcome"). In contrast, unlike the pineapple case (Type 2), the conceptions should not be removed but are a challenge the students address when appropriating scientific norms. In the case of mirabelle, the student recognition of anthropomorphic and teleological conceptions is perceived as positive ("they can already figure it out"). The teacher is thereby constructed as someone who is supposed to guide the students on this path ("guiding"), which is addressed as an instructional challenge of the teaching activity ("sticking point", "obstacles" and "difficult"). The reconstructed goal can also be illustrated by the criticism of the evolution lesson, according to which it did not lead to a change in student knowledge.

Regarding the third dimension of comparison, i.e., the importance of student conceptions for teaching and learning scientific norms, in the case of mirabelle, student conceptions are seen as a problem of teaching and learning scientific norms since they are constructed as an obstacle. In a metaphorical sense, they complicate the student access to scientific norms. Therefore, they represent a practical teaching and learning challenge ("sticking point" and "obstacles that you kind of have to overcome"). This situation can also be illustrated by the fact that addressing student conceptions is described as a practice that requires working through difficult issues ("to think about when to interrupt the students" and "how do you make sure that they can truly express"). In contrast to the pineapple case (Type 2), student conceptions in the mirabelle case (Type 3) are viewed not only from a teacher's perspective as a teaching problem but also simultaneously from a learner's perspective as a problem learning scientific norms.

Type 4: avoiding student conceptions through an awareness of coexisting explanations

The maracuja case is an individual interview with a teacher who has been working at a comprehensive school for six years. The content of the transcript excerpt is part of the opening passage, in which the teacher talks about the learning and teaching of evolution and how to address student conceptions.

> Am: I have noticed several times in newspaper articles, in scientific or in reasonable renowned daily newspapers, they write something about evolution which is simply pure Lamarckism. And that stands there and is accepted like that and everybody reads that and nobody is bothered by the fact that it is actually factually wrong. But everybody can exactly understand the idea, because we think lamarckistically °because that is our experience.° (12) [..] So she has good students sitting in the course who have fully grasped this and can also apply it, but you can clearly see from the speech contributions that there are also at least a handful who do it just as wonderfully wrong as you can expect and how you actually try to somehow drive it out of them. We have made a similar observation, where we have done it the other way around, actually. We have looked very closely first at all these evolutionary processes at the molecular level and at the population level and then at the end we have said ok, and the theory of how a characteristic now spreads, how evolution takes place overall, looks like this. And regardless of the order, the result seems to be pretty similar. (3) Because there was also the personal concept and the experience of adaptation and the idea of I 'can adapt', which I think the teacher actually discussed with them. We transfer this experience/ this experience is so deeply ingrained in our thinking that we also transfer it to these processes, I think, automatically and naturally and unreflected and unnoticed, so to speak. So to constantly reflect on this simply requires a high level of attention when speaking. I notice this myself in oral examination situations or in teaching situations, that I very quickly tend to provide such an unclean explanation, which in the end actually provides a final justification in terms of the result. Because that is how we speak and that is how we think.
> (Transcript: l.70-96)

According to the base type, the teacher positions himself, as in all cases of the sample, as a person who can evaluate the teacher and the students ("fully grasped this"). In the diagnosis of student conceptions, a subsumptive–generalising observation attitude is adopted, in which student statements are classified under categories ("Lamarckism", "lamarckistically", and "final justification").

Regarding the first dimension of comparison, i.e., the way of relating student conceptions and scientific norms, a tension and a dialectical relation can be reconstructed in the maracuja case. The students, like other persons, are constructed as persons who must continually work through two tense explanations of evolution. This situation can be illustrated by the assumption that students transfer their conceptions about adaptation "automatically and naturally" to evolutionary biological phenomena. Therefore, the student conceptions can be both in line and in conflict with scientific norms. The conflict can be illustrated by the scientific concept of adaptation being constructed as incompatible with and in contrast to student conceptions. The fit can be illustrated in other transcript passages where the scientific concept of population is constructed as compatible with the rejection of anthropomorphic ideas. This conflict between a scientific explanation and an explanation using student conceptions is also evident in the construction of a discrepancy between the goals that should be achieved and the goals that can be achieved ("how you actually try to somehow drive it out of them").

Regarding the second comparative dimension, i.e., the goal in addressing student conceptions, an avoidance of student conceptions in explaining evolution through an awareness of its coexistence with scientific norms can be reconstructed in the maracuja case. This goal can be illustrated by the fact that, in contrast to Types 2 and 3, student conceptions are constructed as something that cannot and should not be eliminated or changed through instruction. This is because they are seen as belong to the students and conceptualised as inevitable ("because that is how we speak and that is how we think"). Personal experience is seen as one cause ("the experience of adaptation"), and student conceptions are assumed to remain in the students' minds, even though they use scientific norms to explain evolution. The students should be able to distinguish between their conceptions and scientific norms, and they are not supposed to use their possibly still-existing conceptions to explain evolution. That is, ongoing reflection is constructed as a challenge for the teacher and the students and requires consistent work and effort ("to constantly reflect"). Comparing cases reveals that the vision in the case of maracuja is oriented towards contingency, according to which goal achievement is possible, but at the same time is not or cannot necessarily be achieved ("as wonderfully wrong as you can expect"). In contrast, goal achievement in the other types is constructed as something that can be achieved under certain conditions regarding the teaching activity, and failure tends not to be constructed as an expectation. This situation can also be illustrated by the fact that the student conceptions that reoccur in the evolution lesson are not surprising in the maracuja case but correspond to the teacher's own experiences.

Regarding the third dimension of comparison, i.e., the importance of student conceptions for teaching and learning scientific norms, in the case of maracuja, the student conceptions are understood as significant experiential knowledge, which can be conducive or obstructive for learning and teaching scientific norms. Student conceptions are constructed as hindering learning insofar as they can prevent students from using and/or appropriating scientific norms to explain evolution ("we transfer this experience"). Thus, the formulation of an "unclean explanation" of adaptation is constructed as a central practical challenge in addressing student conceptions. At the same time, student conceptions are understood as conducive to learning since an examination of them and the respective formulations can contribute to an understanding of scientific norms ("to constantly reflect").

Discussion

Through comparative analyses, commonalities (base type) and differences (four ideal types) between our cases were reconstructed, which can be interpreted as a routine way of seeing and talking about addressing student conceptions in an evolution lesson. Thus, the types represent an "analytical generalisation" (Firestone 1993), so the reconstructed orientations are also of general importance beyond the specific case. Based on the research approach, we assume that the developed typology can adequately describe how preservice and in-service biology teachers talk about addressing student conceptions in an evolution lesson and the tacit knowledge that guides their actions. A central argument is our assumption that the typology is characterised by high ecological validity, since the audio data show authentic discussions about an evolution lesson. We also assume adequate reliability since we can reconstruct similar patterns by talking about the evolution lesson across different issues within one case and between different cases. A reliable and valid typology seems to be a central prerequisite for the findings to identify aspects of teacher education and professional development. To make suggestions for evidence-based teacher education courses, fits and differences are discussed between the reconstructed frameworks of orientation and evolution education as well as

professional theoretical norms. From this comparison, reflection occasions for teacher education can be derived, and the question can be pursued of how a cross-type and type-specific professionalisation can be supported.

In his studies of professional vision, Goodwin (1994, p 616) elaborates how members of a profession share a particular way of vision, which he describes as "socially organized perceptual frameworks" that transmit norms. Our reconstructed base type of professional vision supports this finding of Goodwin (1994) regarding the teacher profession. Thus, we could reconstruct some commonalities concerning the way teachers are doing professional vision. In all cases, an evaluation mode was reconstructed. Across all cases, the participants assess the teacher's actions and the student learning process. The high importance of an evaluation mode when talking about lessons has also been highlighted in other studies (e.g., van Es and Sherin 2010; Schiller 2019). From the bachelor's student to the experienced teacher in our sample, all of them position themselves to be legitimised and capable of evaluating and optimising the evolution lesson. In this process, scientific norms take on decisive importance since the teacher and student statements and their conceptions about evolution are evaluated regarding scientific correctness. Based on (rigid) categories and their own expectations of normality, the preservice and in-service biology teachers construct a reality of the lesson and its evaluation, the validity of which is widely regarded as objectively unambiguous. This process is useful for professionalisation, since teachers are expected not only to teach well but also to be able to determine what is considered a good-quality lesson. In addition to the many advantages that the evaluation routine brings (e.g., as a starting point for the discussion of alternative actions for addressing student conceptions), challenges also arise. Based on Helsper's (1996) structural–theoretical approach, the evaluation routine poses the risk that the teachers do not reflect on the appropriateness of their own perception. For professionalisation, preservice and in-service teachers must address their nonknowledge when talking about lessons and position themselves as learners. Knowing the limits of one's own vision makes it possible to maintain a sensitivity towards the challenges faced by professionals and to endure them (e.g., uncertainty (ibid.), regardless of the rules (Shulman 1986).[3] Accordingly, professional vision is also characterised by the fact that not everything about the lesson can be said with certainty and open questions must remain. This situation can be illustrated by another commonality of all our cases, namely, the dominance of the subsumptive logic when using deductive categories. Student statements are classified under categories of student conceptions and/or under the categories "right" and "wrong". As research on student conceptions shows, student statements are interpreted, and a connection is made to an underlying conception. An orientation towards unambiguity is problematic since misinterpretations of student statements are possible and not every concept can be clearly identified. Evolutionary explanations require the use of lexically ambiguous language (e.g., select and adapt; Rector et al. 2013). Reasoning from short student statements to conceptions can, thus, be problematic. The teacher in the maracuja case (Type 4) argues that using teleological formulations acts as a linguistic shortcut that takes less time compared to the theory of evolution. Thus, when the student conceptions are reconstructed from their statements, a distinction must be made "between conventional lexical meanings of expressions and intended meanings of expressions, expressing individual conceptions" (Rector et al. 2013, p 28). However, it is useful to talk about addressing student conceptions using deductive categories. In many of our cases, the diagnoses of student conceptions were made using categories based on teleological and anthropomorphic ideas. Explicit knowledge about the categories of student conceptions is important; otherwise, they would probably not be seen in evolution classes. The question is which categories should be used for diagnosis discussed by Fischer et al. (2022) and Hartelt et al. (2022).

The dominance of an orientation to the requirements of the learning matter can be reconstructed in all four types. In all cases, the students should acquire scientific norms so a generalised standard applies equally to all. In the literature, the coexistence of scientific norms and (anthropomorphic) student conceptions can be a legitimate instructional goal (Combe and Gebhardt 2012). However, this situation could not be reconstructed empirically. Moreover, student conceptions were not constructed from an appreciative perspective as an enrichment or resource for teaching and learning scientific norms in any of the cases. Type-specific professionalisation approaches should consider that an orientation to the person of the learner is less important in Types 1 and 2 than it is in Types 3 and 4 since the student conceptions are constructed from a deficit perspective as a clear contrast to scientific norms (right–wrong dualism). Student conceptions are irrelevant in teaching–learning processes (Type 1) or should be removed (Type 2), as assumed by classical conceptual change theory (Posner et al. 1982). The dominance of a deficit perspective on student conceptions has also been elaborated in other studies on

[3] Teachers' actions in addressing student conceptions are also structured by the indissoluble tension between an assumed effect of teaching on students' appropriation and their uncertainty. How the cases in our sample address this uncertainty and the resulting antinomy is discussed elsewhere: Steinwachs and Martens (in preparation).

professional vision (e.g., mathematics: Jilk 2016). The orientation to the person of the learner is more distinct in Type 3 since, in principle, the student conceptions can also contain appropriate aspects. Thus, they are constructed as a meaningful starting point for the teaching and learning processes. Moreover, student conceptions should be transformed into scientific norms. This situation is in line with the notion of conceptual development (Duit et al. 2012). Type 4 shows the strongest orientation to the person of the learner because from an approving perspective, the student conceptions are constructed as experiential knowledge. The discrepancy between scientific norms and student conceptions cannot be resolved in the evolution lesson, and students should be enabled to distinguish scientific and everyday concepts to avoid using everyday conceptions when explaining evolution. This situation is in line with the evolution education norm of an awareness of the difference between student conceptions and scientific norms and their context-specific appropriate application (e.g., development of metacognitive skills: González Galli et al. 2020; comparison of everyday language formulations and technical language: Sinatra et al. 2008).

The results are subject to some limitations. Our research approach does not allow us to draw conclusions about the representativeness of the ideal types. In addition, well-founded statements cannot be made about the distribution of the three groups from our sample across the four types. Furthermore, a real classroom setting can be assumed to provide more factors that influence professional vison that cannot be replicated with a lesson video. This context includes existing relationships between students and teachers as well as previous situations that can structure professional vision. In addition, despite the theoretical sampling strategy (Glaser and Strauss 2009), the reconstructed types can be further differentiated by additional cases. Type 4 is understood as an approximation to an ideal type since it is based on one only case. The challenge is to find preservice or in-service teachers who comprehensively put students and their conceptions at the centre of the teaching when the standardised, rule-governed system of school strives for selection and homogenisation (e.g., regarding achieving scientific norms). Moreover, other orientations can be reconstructed in the vision of addressing student conceptions concerning other content areas of biology. This situation needs to be investigated in further empirical studies. Since we do not assume that in other content areas, completely different experiences are had regarding the addressing student conceptions, we consider it plausible that the orientations regarding the base type and further orientations can be reconstructed here as well.

Our results illustrate that in teacher education, important tasks include not only teaching explicit knowledge and competencies but also discussion and reflection of tacit knowledge. Teacher education often refers to models of explicit teacher knowledge, especially with reference to Shulman's distinction between the three facets of content knowledge, pedagogical content knowledge and pedagogical knowledge Shulman (1986, 1987). As numerous studies have already shown, these three facets of knowledge are of central importance for enacting a professional vision (e.g., Fischer et al. 2021, 2022; Kramer et al. 2021). We argue, in the context of our results and as discussed by Shulman (1988) and Schön (1983), that we should include tacit knowledge when reflecting on professional vision. This situation can be illustrated by the fact that, among the variety of conceptual change theories, only "cognitive conflicts" (Posner et al. 1982: 225) are *explicitly* addressed in our cases. Meanwhile, various theories play roles in the form of tacit knowledge, as the exemplary discussion of the four ideal types has shown. At the same time, the diversity of approaches and their contradictions are not relevant during the conversations—either explicitly or implicitly. We see one approach for the professionalisation of professional vision in the requirement of Shulman (1988: 33), who demands, "While tacit knowledge may be characteristic of many things that teachers do, our obligation as teacher educators must be to make the tacit explicit." In many of our cases, the challenge arises of the discrepancy between explicit and tacit knowledge. In the rosehip case (Type 1), it is explicitly demanded that the student conceptions must be refuted with technical literature and on the other hand the participants share an orientation that the student conceptions are not significant. Thus, the case is oriented to the fact that the students acquire scientific norms completely, and the case is not simply about relating the norms to the student conceptions. Therefore, some teachers cannot do everything they explicitly know. On the other hand, in the execution of the teacher's professional vision in the case of maracuja (Type 4), considerations of the antinomy construct (*Sachantinomie*) are significant but are not explicitly discussed. Thus, some teachers do not explicitly know everything that they skillfully do.

Based on the analyses, we argue that the results may provide approaches for initiating a professionalisation of vision, particularly regarding the reconstructed evaluation mode, the discrepancy between explicit and tacit knowledge, the described differences between the frameworks of orientation and evolution education and professional theoretical norms. The study of cases, which can be developed with the help of authentic video lessons,

allow these teacher education challenges to be addressed (for initial perspectives see Steinwachs and Gresch 2020). A central argument is that due to antinomy (*Sachantinomie*), a standardised way of addressing student conceptions cannot be formulated. Rather, an understanding of the case at hand, which has a more extensive context, is necessary to clarify which possible actions can claim professionalism. One form of casework seems particularly promising: The case is a factual basis of a reflexive engagement with an evolution lesson and becomes an opportunity to reflect tacit knowledge that structures one's own professional vision. The types reconstructed in the study can act as starting points for reflecting on one's own implicit orientations and they can help teacher educators develop learning opportunities as one better knows what to expect. When preservice and in-service teachers talk about addressing student conceptions in an evolution lesson, many of their statements are observations that can be better understood with the help of the typology. Moreover, the typology can serve as a stimulus for "frame analyses" (Schön 1983, p 311). For this purpose, i.e., a practical reflection in the sense of Schön's (1983) concept of reflection-in-action, preservice and in-service teachers can reflect their tacit knowledge with the help of evolution education norms, thereby learning about themselves and their own location-boundedness. For this purpose, questions based upon Schön's concept of reflection-in-action (Schön 1983, p 49–50) seem useful: "What features do I notice when I recognize this thing? What are the criteria by which I make this judgment? What procedures am I enacting when I perform this skill? How am I framing the problem that I am trying to solve?" This process could help teachers to recognise and reflect on their implicit routines of action and constructions in vision.

Expectations should not be too high of the possibilities of professionalisation by studying cases because it is difficult to change ways of addressing student conceptions in evolution classes. This reflexive path is laborious but necessary to address tacit knowledge and thus enable effective change. However, when studying cases in evolution education, an evaluation mode and an orientation towards optimisation need not be completely avoided. These approaches are necessary for developing argumentatively justified alternative actions for addressing student conceptions. For this purpose, antinomy (*Sachantinomie*, Helsper 1996) can serve as a heuristic for reflecting on the orientation to the person of the learner (Duit and Treagust 1998) and an appreciative perspective of student conceptions, in particular. The heuristic and distinction between product and process quality could be useful. Thus, the fact that student conceptions have changed to a certain extent might not be the only criteria for the evaluation of addressing student conceptions. Therefore, in addition to how the teaching effects change in the student conceptions, the question also arises of *how* the conceptions are addressed. Thus, good ways of addressing student conceptions can also consist of an appreciative attitude towards students and their conceptions, even if these do not change because of the teaching activities. Controversial discussion about alternative actions should consider which student conceptions are important and should be addressed in the classroom.

Without being able to justify this claim in detail here, from our perspective, another promising approach is a professional development programme called *video clubs* (Sherin 2007). In such clubs, a group of teachers watch and discuss videos of their own classrooms in a collegial setting. Other professions could participate in a video club in addition to teachers (e.g., professionals from the relevant didactic fields). The different professional visions, which should be valued equally, could be used for mutual professionalisation. This could reduce the problem that Lefstein and Snell (2011) identify, according to which differences between the teacher and the researcher perspectives are viewed as deficits and as a sign of the insufficiently professional vision of teachers. Here, it seems useful to consider Goodwin's (1994, p 606) conclusion that each profession has its own practice to see and that "(all) vision is perspectival and lodged within endogenous communities of practice". Therefore, working in video clubs could lead to a professionalisation of professional vision by contrasting the participant orientations.

One perspective for follow-up studies is to make the practices of teacher education regarding the professionalisation of vision the subject of the empirical research to describe and better understand (de)professionalisation processes. For this purpose, the presented formats of teacher education, casework and video clubs can be examined. Such research could help identify further challenges and opportunities in teacher education and would thus be valuable for improving the teaching and learning of evolution.

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