NARRATIVE AND METAPHOR AS CONCEPTUAL TOOLS FOR UNDERSTANDING EVOLUTION THEORY

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Abstract

Human beings 'make sense of the world by telling stories about it' (Bruner 1996, p.130). Thus, meaningful narrative explanations cannot simply be replaced by scientific conceptions that are contradictory to the learner's experimental realism (Gropengiesser 2003). This is specifically relevant in those domains of science where conceptual change in favour of scientific explanations is difficult to achieve, e.g. the theory of evolution. Learners tend to make sense of the phenomena in their own, non-scientific way that includes intentional and teleological explanations.

This paper focuses on the role of a so-called 'narrative mode of thought' (Bruner 1996) for meaning making in the science classroom. We present results from a study in lower secondary school (age 12-13 ys.), exploring how students make sense of adaptation phenomena. Before and after a teaching sequence on the theory of evolution, students explained the evolution of modern whales from their terrestrial ancestors by writing narrative or non-narrative texts on the issue. Text analysis, combined with student interviews, revealed students' conceptions and their

individual methods of making sense of adaptation phenomena. Those students who chose to write narratives often used common story plots and motives. Some of these plots, e.g. 'social outcast'-stories, appeared to help students to understand key concepts of Darwin's theory. The data suggest that the narrative paradigm is appropriate to investigate and to strengthen individual and emotional aspects of understanding science. However, the evidence also puts into question too generalized assumptions on the two 'modes of thought'.

1 Introduction

> For a person who wears glasses and suffers from asthma, as I do, survival in the Stone Age wouldn't have been easy. If a rhino had tried to spear me – well rhinos don't spear people, but if I was threatened, I might have spotted it too late. I wouldn't have been able to run fast enough due to my lungs not working so well. So I would have been killed and wouldn't have had the chance to pass on my genes due to my defects. (Katharina, 18 ys.)

This passage from an interview with a German school student illustrates how deeply narrative can be involved as soon as learners start explaining complex biological phenomena. The interviewer had asked Katharina to explain what natural selection was about, and after trying hard to formulate an abstract definition to this notion, she eventually came up with this imaginative little story. The stone-age scene immediately reminds the reader of Darwin's metaphorical conceptualization of natural selection as a struggle for life. This metaphor literally condenses a complex process to a concrete, observable event, a physical confrontation. In a subsequent step of concretisation, Katharina elaborates the idea of natural selection as being a 'struggle' to a narrative structure, thereby filling the roles of the adversaries with a mighty animal and –

in the inferior position – herself. Obviously she imagines herself as a potential victim of natural selection, due to her physical ‚defects'. The imaginary example illustrates Katharina's belief that if nature had had its will, defective individuals like herself would have been eradicated long before. This example may raise the question: What is the meaning and the value of narratives like this one for the science classroom?

2 Theoretical Background

2.1 The Narrative Predisposition

It is known that certain meaning categories dominate the child's interest and attention during the period of early language acquisition, e.g. people and their actions (1). Furthermore, young children show an early readiness to mark what is unusual (2), they master the subject-verb-object order of indicative sentences relatively early (3), and they use perspective, primarily through prosodic features (4). Interestingly, these four categories are also basic requirements of narrative. Bruner (1990, p. 79) concludes from this evidence that 'it is the human push to organize experience narratively that assures the high priority of these features in the program of language acquisition'. Stories and myths have been an essential part of human culture long before the rational period. Narrative is believed to play an important role in meaning making because it is very close to fundamental human experience and behaviour. E.g. in stories, actions have reasons, not causes. Unlike cause-effect relationships, intentional states such as beliefs and desires invite the reader or listener to judge them in normative schemes. This implies sometimes breaches of convention or unusual points of view that challenge the reader's own interpretation of reality.

Narrative realities

In the last 25 years, narrative psychology and the related disciplines have extended the investigation of the role of narrative from the early, relatively narrow cognitive approaches to a variety of functions of the human mind such as identity (for a review see Echterhoff & Straub 2003). The research was influenced by the constructivist paradigm. Narrative is no longer reduced to a mode of writing or communicating, but viewed as a mode of thought that creates an entire reality of its own. Bruner (1996) considers narrative particulars and narrative genres as a predominant way of interpreting everyday events. Since creating and maintaining an image of ourselves means to interpret the countless episodes that we experience and integrate them into a coherent self, our individual identity can be viewed as a narrative reality, imposed on a whole lifespan. But Bruner's phrase 'it takes a story to make 'sense' is equally valid on a cultural level: the joint narrative accrual of history is just one example of how humans work together mentally in order to make sense of their world (1996, p.146). Science, as much as history, is a cultural enterprise that owns its achievements not only to pure application of the scientific method but also to various particulars, coincidences and personal construals of meaning.

2.2 Narrative in the Science Classroom?

The 'power of story' has become an issue in science teaching, and explanatory stories are part of curricular recommendations (Millar & Osborne 1998). However, there is no comprehensive theory and very little data concerning the use of narrative in the science classroom (e.g. Kurth, Kidd, Gardner & Smith 2002). Bruner (1990) stresses the

importance of story for meaningful understanding and the special characteristics of paradigmatic and narrative thinking (Table 1).

	Narrative mode	Scientific mode
Method	Particular events, actions and their reasons are described. A problem is at the centre.	The systematic study of phenomena and logical thinking help to identify relations in the natural world.
Goals	To make meaning of experiences, to fascinate, to convince, to entertain, to create identity	Tested knowledge such as theories, natural laws and explanations
Criteria	coherent, true-to-life	Verifiable, free of contradictions

Table 1. Two Ways of Interpreting Reality (Bruner 1996, modified). Bruner starts from the assumption that there are two distinct modes of thought to be dealt with: the narrative and the scientific (orig. 'paradigmatic') mode, each of them following different rules and objectives.

The gap that opens between the everyday logic applied by the learners and the scientific conceptions can also be described as two 'modes of thought': a narrative mode and a paradigmatic (scientific) one, each of these with universal characteristics (table 1). Human beings 'make sense of the world by telling stories about it' (Bruner 1990, 1996). Bruner criticizes that only the scientific mode is allowed in the science classroom. Instead, a key to conceptual change may lie in the use of both the narrative and the scientific mode as well as 'metacognitive sensitivity' (Bruner 1996) in order to allow students not only to learn the appropriate scientific conceptions but also to give them an individual significance.

Kurth et al. (2002) have investigated classroom conversations in elementary school. Their results depict how an interplay between the two modes develops and helps children to make sense of the natural world. Meaningful narrative explanations cannot simply be replaced by scientific conceptions that are contradictory to the learner's experimental realism.

Narrative and Evolution Theory

This study attempts to explore potential benefits and problems of the narrative mode in the science classroom, particularly in the field of evolution theory and Darwinism. Darwin's Theory of Natural Selection plays a key role for biological understanding (Darwin 1872, Mayr 1984). Some of its essential concepts, such as the biopopulation, differ fundamentally from any physical or chemical entity. Evolution theory therefore constitutes what Mayr (2004) called the 'autonomy' of biology as a science. Furthermore, explaining evolutionary phenomena requires considering natural 'laws' of selection, as well as unique events and random variation. Explanations for species change usually combine the nomological aspects of natural selection, predicting the survival of the fittest and the accumulation of changes in the population's gene pool, with rather 'narrative', contingent aspects of natural history, such as climate changes or catastrophes.

Maybe it is partly due to this complexity that evolution theory is difficult to grasp for students. Conceptual change in favour of scientific explanations is obviously hard to achieve in this domain (Deadman & Kelly 1978, Halldén 1988, Wandersee et al. 1995, Baalmann et al. 2004, Zabel & Gropengiesser 2011). Learners tend to make sense of

species evolution and adaptation phenomena in their own, non-scientific way that includes intentionalist and Lamarckian explanations. The cognitive linguistics framework (Lakoff 1990, Lakoff & Johnson 1999, Gropengiesser 2003) has proved to be quite helpful in exploring and explaining how students make sense of scientific phenomena such as heat (Amin 2001) and biological adaptation (Weitzel 2006). Apparently, conceptual metaphor and narrative are both powerful tools of everyday meaning making, and we have only begun to explore the relevance and the specific role they play when it comes to the understanding of certain scientific domains, such as evolution theory.

2.3 Adaptation in the Framework of Cognitive Linguistics

According to conceptual metaphor theory (Lakoff 1990, Lakoff & Johnson 1999), thought is embodied, that is, our basic conceptions grow out of bodily experience, i.e. perception, body movement, and experience with our physical and social environment. Lakoff (1990, 269f.) distinguishes between basic-level concepts such as »cat«, »sit« or »mat«, and kinaesthetic image schemas such as up-down, centre-periphery, front-back, or inside-outside. Wherever we lack experience, e.g. in abstract domains, we tend to use these kinaesthetic schemas in order to imagine this target domain, mainly by means of a metaphor. In other words, conceptual metaphors serve as unidirectional projections of a schema from a source to a target domain (Lakoff & Johnson 1999). There is convergent evidence from neural science to the theoretical framework of experientialism. The structure of certain schemas was found to correspond to neural structures of our brain (Gallese & Lakoff 2005).

In the framework of cognitive linguistics, adaptation can be considered a relatively well-investigated concept. We have good knowledge of the conceptual metaphors that the learners use in order to explain how and why species change in time. Weitzel (2006) documented that adaptation (*Anpassung* in German) is a cognitive model based on physical experience. Individuals *adapt* themselves or certain objects up to the point where they fulfil certain criteria. The everyday idea of adaptation is a cognitive model, depicting an active, intentional process initiated by an individual. Subsequently, if the learners metaphorically transfer this cognitive model to the context of evolution, they will consider species adaptation to be active, intentional and individual, too (figure 1) – and many studies indicate that they do so indeed.

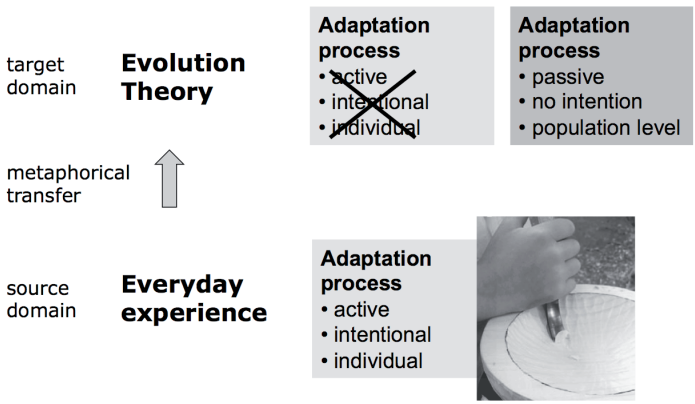

Figure 1. Adaptation as a Cognitive Model Based on Physical Experience. Individuals adapt themselves or certain objects up to the point where they fulfil certain criteria. The everyday idea of adaptation is a cognitive model, depicting an active, intentional process initiated by an individual (Weitzel 2006). The metaphorical transfer of this cognitive model to the context of evolution results in inadequate understanding of biological adaptation.

3 Research Objectives

The main focus of this paper is to investigate the role of narrative in evolution teaching, and to explore its function in the process of individual meaning making. Based on the analysis of case studies, we attempt to draw general conclusions as to the potential benefits and difficulties narratives in the learning of evolution theory.

4 Research Design

Our naturalistic study involved five classes from three different grammar schools (*Gymnasium*), all situated in small towns in northern Germany. The sample encompassed a total of 107 lower secondary students (grade 7, average age 13). All students followed a teaching sequence on evolution theory over a period of five weeks, about 10 lessons in all, designed according to the theory of conceptual change (Posner & Strike 1992) and cognitive conflict (Duit & Treagust 1998). The sequence had been tested in school and finally published (Giffhorn & Langlet 2006). During this study, all students were taught by their usual biology teachers. In an initial phase, students were to explain whale evolution based only on their pre-instructional knowledge. Then, Lamarck's ideas were presented to them as a scientific theory of evolution without labelling it as historical. Most students felt confirmed in their preconceptions, conceiving evolution as a process of individual adaptation, initially triggered by environmental conditions and inherited by following generations. The students were then confronted with Weismann's experimental findings (Weismann 1902) in order to shatter their belief of the inheritance of acquired traits and make them actively search for a new explanation for adaptation phenomena. Then their attention was directed towards the breeding of domestic animals.

Darwin's theory of natural selection was introduced and applied to various evolution phenomena.

The data were collected by a writing assignment at the beginning and end of a teaching sequence, in which the students were asked to explain the evolution of modern whales from their terrestrial ancestors (Zabel 2009, p. 126-128). The assignment was almost identical in the pre- and post-test and was illustrated with three naturalistic drawings: a contemporary blue whale and two extinct whale ancestors, one terrestrial and one semi-aquatic. In this way, we collected a total of 214 pre- and post-instructional texts from the 107 students of the sample group. In addition to the text data, a total of 30 students were interviewed individually, focusing on the writing process, conceptions of evolution and their individual significance.

5 Data Analysis

5.1 Text Sample (n = 214)

All student texts (pre- and post-instructional) were analysed for explanations of whale evolution, using Qualitative Content Analysis (Mayring 2007). The students' explanations were condensed to nine explanation patterns and formulated. According to the Model of Educational Reconstruction (Duit, Gropengiesser & Kattmann 2005), the corresponding scientific conceptions are needed for a mutual comparison. For this purpose, we used Weitzel's (2006, p. 41-79) thorough clarification of the concept of 'adaptation', based on the theories of evolution by Lamarck, Darwin and Mayr. The mutual comparison of student and scientific conceptions led to conceptual frontiers, each of them marking one major learning task on the way towards a Darwinian explanation. The conceptual development of all 107 participants was then assessed according to the

explanations they used before and after the instruction. These longitudinal data were visualised as learning trajectories on a mental landscape (Fig. 2, see also Zabel & Gropengiesser 2011).

5.2 Case Studies (n = 5)

All 30 texts of the focus sample were transcribed from their handwritten originals, keeping the original spelling and stanza. They were then interpreted in a hermeneutical procedure, encompassing three steps with respect to different focuses. Interview data were used to validate and complete the text analysis. We performed an in-depth analysis of five case-studies, all of which showed evidence for meaning making processes. The sample of n = 5 was theory-based; it was selected to characterize narrative meaning making processes according to the theoretical background developed previously in this paper. Each of the five case studies consists of a text and a related interview (see Zabel 2007, Zabel 2009).

Analysis step 1: Narrative discourse and narrative syntax

The narrative dimension of the sample texts was assessed in two different dimensions. The first analysis step focused on narrative discourse. The texts were scanned for obvious indicators of narrative, e.g. words such as 'I' or phrases such as 'our story begins here'. Taking into account such indicators of narrative discourse, the texts were roughly classified as narrative, partly narrative or non-narrative, according to general narratology (e.g. Martinez & Scheffel 2003).

In a second step, the 'deep structure' of the texts was analyzed. This means describing the basic components of a narrative, according to the concept of narrative syn-

tax (Labov 1977). In addition, action- and non-action elements were identified (Sutton-Smith 1981). This approach was initially developed to analyze Russian folk tales (Propp 1968), but has been developed since to suit the requirements of sociological and psychological research better than the classical narratology with its more literary context. Elements to be identified are figures, motives and events that constitute the action and the central disequilibrium that the story is built around, but also non-narrative elements such as a moral or an additional explanation given by the storyteller.

Analysis step 2: Explanative Function and student conceptions on adaptation

The explanation for whale evolution given in the text was analyzed and compared to students' explanations for adaptation processes described in previous studies (Baalmann et al. 2004, Weitzel 2006). Similarities with and differences to scientific explanations for evolution processes were examined, including the subtype of a 'narrative explanation' as found in Norris, Guilbert, Smith, Hakimelahi & Phillips (2005). Assuming that a 'narrative construal of reality' may have repercussions on the type of explanation used (Bruner 1996, p. 136), the analysis tried to carefully consider the possible effects of the narrative discourse when describing the explanations found in the texts.

Analysis step 3: Meaning making by narrative construal of reality

In order to retrace meaning making processes, the interviews were now integrated in this last step of the analysis. The students' understanding of adaptation processes expressed in these interviews was compared to the corres-

ponding passages in the narratives that they had written. Interview evidences also allowed relating particular features of stories to their author's attitudes, experiences or biographic details. Our aim in doing so was to reconstruct individual processes of meaning making through which the authors had established individual links between the issue of whale evolution and their conceptual system. The underlying idea is that narratives are particularly suitable to look for such links, because 'we live most our lives in a world constructed according to the rules and devices of narrative' (Bruner 1996, p. 149). Starting from this assumption, it is interesting to examine how and to what degree the individual understanding of a biological process is interwoven with everyday experience in a narrative. To do so, text and interview data were repeatedly interpreted and related to each other. This interpretation of the data was brought into agreement with other researchers at the occasion of regular workgroup meetings.

6 Findings

6.1 Text Sample

Explanations for whale evolution

Eight patterns of explanations for evolutionary change were identified in the 214 learners' texts (see Zabel & Gropengiesser 2011, p. 146):

(1) Intentional adaptation of individuals
(2) Intentional adaptation over generations
(3) Environment causes evolution
(4) Evolution caused by need
(5) Usage of organs
(6) Evolution through interbreeding
(7) Evolution by variation of a type and natural selection
(8) Evolution by full variation and natural selection

Two of these patterns, no. 7 and 8, are Darwinian' in a broader sense. Whereas pattern no. 8 represents the scientifically correct Darwinian explanation, no. 7 is close and can be considered a preliminary state. The instruction on evolution theory increased the frequency of Darwinian explanations in the post-instructional texts (see Zabel & Gropengiesser 2011).

Both narrative and non-narrative texts contained Darwinian explanations for whale evolution. Those students who chose to write narratives often used common story plots and motives. Some of these plots, e.g. social outcast stories, appeared to help students to understand key concepts of Darwin‘s theory. The social outcast stories in our data are narratives based around a single individual which turns out to have hidden qualities when the conditions change, e.g. when food gets scarce, and thereby manages to survive and become an attractive mating partner (see figure 3, Max).

Our analysis also revealed that three of the rather naïve explanations, no. 1 to 3, exhibit a common metaphorical structure: The pattern that connects them is the action schema, described by Gallese and Lakoff (2005, p. 461) as follows: 'action, that is, a movement executed to achieve a purpose'. Our data suggest that it is the action schema that is responsible for the genesis of three widespread and misleading explanation patterns for species evolution. For a detailed description of method and findings see Zabel & Gropengiesser (2011).

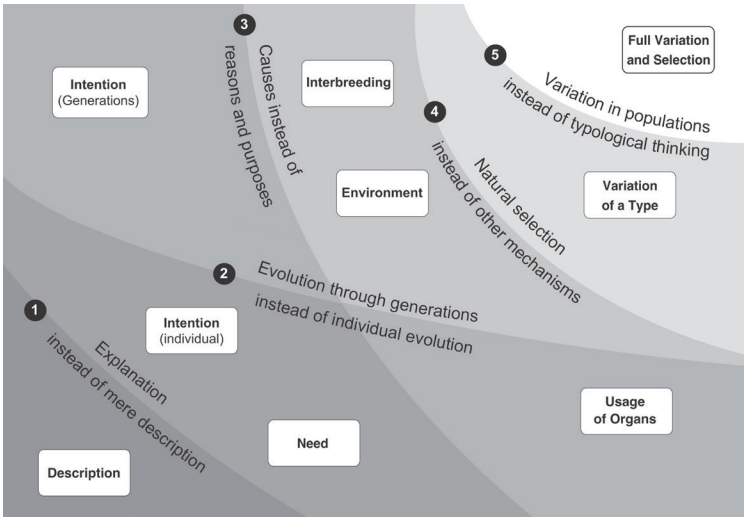

Figure 2. Darwin's Conceptual Landscape. The squares indicate the explanation patterns found in students' pre- and post-instructional texts on whale evolution (n = 214). The positions of the squares, as well as the areas and frontiers that structure the landscape result from a mutual comparison between the explanation patterns and key ideas of Darwin's theory of natural selection (Darwin 1872). This comparison is based on the Model of Educational Reconstruction (Duit et al 2005). The higher and the further to the right an explanation is located on the landscape, the more scientifically adequate can it be judged, because it shares more common features with the 'target' explanation for evolution, the theory of natural selection.

6.2 Case studies

For an in-depth analysis of the interview sample (n = 30) and all five case studies see Zabel (2009). Two of the five case studies are presented here, one of them (Anna) is based on pre-instructional, the other one (Max) on post-instructional data.

The Whales (Anna, 13 yrs.)

The whales. Who could not know them? These big, beautiful animals. With a length of more than 30 meters and a weight of more than a 100 tons they belong to the biggest animal species in the world (blue whale).
But how did their ancestors live? All this goes back 50 million years. A long, long time before our time. Where our story begins.
The whale used to be a land animal that fed on plants as well as on meat. But then the land got scarce and later on there was more water than land. So the space to live was limited and there was less and less food. Millions of years later, the whale began to live both on land an in the water. His anterior limbs were formed like fins and his tail ended with a mighty horizontal tail fin. They hunted at the coastal waters, at the sea and at the river mouths. This was unusual for land animals. As a consequence, they adapted more and more to the water element. With their new shape, the whales could move more quickly in the water and could catch much more prey like this. On land, they were very slow and were therefore exposed to the danger. For on land, there were many enemies for them. So the whales began to live in the water entirely. There was more food, more space, more prey and less enemies. So the whale grew to the size that it has today. For with over a 100 tons, the whale would be squashed by its own weight on land.
However, one thing still shows to man that the whales were once land animals. They have got lungs, they are mammals and they give birth to live children. For we all know that water animals, like fish for example, breathe with gills and lay eggs from which their young hatch.

Of course this is only a theory, for not even the brightest scientists know how the whales' life really looked like.

Unfortunately, the whales are threatened by extinction today. But as we all know now, whales are beautiful animals. They all have a long history behind them. And we should do everything to protect their lives and to help them.

Evolution of the Whale (Max, 13 yrs.)

Bernd was teased by the other prehistoric whale kids all the time, only because he was bigger and had a longer tail. Besides that, he swam very well.
As more and more children were born, there soon was a famine on the island. Even the youngest ones fought for food. But not Bernd. As he could swim, he gathered his food from the sea. He was an individual. All the pre-whales were broken-down and the females all had a crush on Bernd because he was strong.
Finally he started a family with Susy. Their kids could swim, too. They also started families. And that is how the whales evolved.

Figure 3. Two of the Student Texts Used for Case Studies. Anna's text (above) is pre-instructional, that of Max is post-instructional (below). Both authors were interviewed, so that each case consists of text and interview data.

Analysis step 1: Narrative discourse and narrative syntax

Max classified his text as a 'story' (*Geschichte*). Indeed he has created a fictitious whale-storyteller that gives an account of his own evolution, which is a clearly a narrative discourse. In the narrative syntax analysis, crucial elements could be identified (figure 4).

Anna's text shows a more heterogeneous picture. There is no whale storyteller, and she considers her text to be non-narrative. However, the text provides all necessary psychological elements, such as complication and resolution, to be read as a story (figure 4). The text consists of a central narrative, framed by an introduction and a final passage. These framing passages are non-narrative, which is not unusual for stories. They obviously have communicative functions closely associated to the story itself: The introduction (lines 3 to 7) describes the beauty and the importance of today's whales ('who could not know them?', line 3), thereby setting the scene for the narrative middle part, which is explicitly introduced in line 7 by the phrase 'where our story begins'. This story is equivalent to the whales' natural history, which is later referred to in the final passage of Anna's text (line 28): 'As we all know now…they all have a long history behind them[1]'. Therefore, despite the fact that it consists of narrative as well as non-narrative passages, the text still forms a unit, which is interesting against the background of Bruner's theory (Bruner 1990, Bruner 1996, see chapter 2.2). The non-narrative passages can well be interpreted as accessory non-action elements of the central story in the sense of Labov (1977).

1. In german, there is only one word for „story' and „history': *Geschichte*.

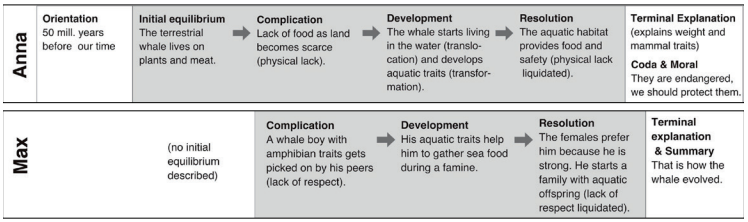

Figure 4: Structural Analysis of a Pre- and a Post-instructional Text (Anna, Max). This type of analysis focuses on the deep structure or 'syntax' of texts by identifying narrative elements (grey sections) and non-narrative elements (white sections), according to a generalized story scheme (Labov 1977, Sutton-Smith 1981).

Analysis step 2: Explanative Function and student conceptions on adaptation

In this step, the texts are being analysed as to how they explain whale evolution. The explanations are analysed for their causal relations and compared to the scientific theories that the students became acquainted with in class. In a subsequent step, interview data of the respective student are integrated in this analysis to validate and precise the result of the text analysis and find out more about the learner's conceptions on evolution.

Anna (pre-instructional)

Anna's text (figure 3) shows some causal conjunctions such as 'so' (9, 17,18), 'as a consequence' (13), 'therefore' (16) and 'for' (16). However, the dominating conjunction 'so' is rather vague. It expresses that one thing led to another, but does not precisely mark the preceding event as a cause of the following. Even more important, the crucial passage in lines 10 to 12, where the change

of habitat and the physical adaptation process are first described, lacks any conjunction at all. Instead, the author gives an account of the events that followed each other. The same type of vague causality is found in the context of the physical adaptation process twice: in lines 13 (*as a consequence*, they adapted more and more to the water…) and 18 (*So* the whale grew to the size…). These physical adaptations make sense under the conditions described previously, they were simply *needed*, and according to the text, that is obviously a sufficient cause for them to happen.

To sum up this result: the explanative function in Anna's text is fulfilled by purely descriptive passages and some vague causal relationships that do not state cause and effect clearly. Also, there is no explicitly mentioned intention in Anna's text. With respect to the categories of our conceptual landscape (figure 2), Anna's explanation is best characterised by 'Description' (it just happened) in some important passages and 'Need' in others (it happened because it was necessary). Anna's interview data confirm the impression of an adaptation concept based on need.

Interviewer:	You write that the whales have adapted. How exactly do you figure that?
Anna:	Well, if there is more water, it is a matter of fact that fins will appear, so that one can live better. Because otherwise it is dangerous to live on the land.
Interviewer:	You are actually describing why it was better for them to live in the water than on land. But that doesn't explain how it worked that they had fins at some point. Do you have any explanation for that?
Anna:	No, I don't.

Max (post-instructional)

Max's explanation integrates two basic components of Darwin's theory of natural selection: (1) the idea that different traits can exist within one population and (2) the conception that the better adapted have more reproductive success. Additionally, Max combines those two ideas with a particular conception of heredity, the dominance of adaptive traits. According to his explanation, the reproductive success of the first 'outcast' finally leads to a new status of homogeneity in the population, because every new outcast hands down his aquatic traits to all his offspring until all the population is aquatic. As to the origin of the aquatic traits, Max propagates the idea of a single deviant specimen that originates from a population of apparently homogeneous conspecifics. Although his explanation reflects a considerably developed conception of natural selection and even female choice, it still differs considerably from Darwin's idea of variation within the entire population (Darwin 1872). In consequence, Max' explanation was categorized as 'Evolution by variation of a type and natural selection' (pattern no. 7, see fig. 2), in contrast to no. 8, "Evolution by full variation and natural selection", which would be truly Darwinian.

The impact of narrativity on explanation

The given explanations may depend on the author's choice of the narrative or non-narrative text option. To assess this relation of explanation and narrativity, all authors were asked in their interviews to comment on this point. Max considers his texts to be a story, Anna declared it as non-narrative. In the interview, Max described some transformations he believed were necessary if he was to write a non-narrative text instead of his story: concern-

ing the narrative discourse, he considered to leave out the first person narrator and straighten the order in which the facts are accounted. As to the story action itself, he would omit the human names and the human feelings attributed to the whales. But apart from these anthropomorphic details of the action, the explanation itself, that is the sequence of events and their causal relations to each other, was unaffected by these transformations. Asked in the interview to explain whale evolution like it should be explained in a biology book, Max stated: 'I would leave out the names, and that he was picked on by the others. But I would still write that this one individual had an advantage compared to the others and could gather food that the other's couldn't reach.'

Analysis step 3: Meaning making by narrative construal of reality

The whales as a threatened group (Anna)

In Anna's story, the backbone of the action is a group that responds to a threat corporately. The action starts with an equilibrium: obviously their terrestrial habitat provides enough food for the whale ancestors. But then the lack of food on land forces them to act. The whales solve their problem jointly by fleeing into the water and later adapting their bodies to the aquatic life. The threat of famine is essential to the explanative function of the text (see above), but it also propels the action of the story of a collective flight and subsequent transformation. Interestingly, the threat to the whales is renewed and transferred to the present days in the final passage: the storyteller deplores that the whales are threatened by extinction today (line 28) and appeals to the reader to protect them, after having stressed that 'they all have a long history behind

them' (line 29). The author refers to the account he has just given, using the eventful past of the whales to plea for their survival in the future. To know what these animals have already jointly gone through reinforces the moral of Anna's story that 'we should do everything to protect their lives' (line 30). Additionally, the author justifies his appeal by reminding the reader that they are 'beautiful animals' (line 29). The interview data help to understand why Anna makes a case for whale protection at all, even if the text assignment didn't require any moral statement.

> The whole world keeps changing, that is what I felt when I wrote my text. In former times, the world used to be better or worse, and this keeps changing on and on. So the world may look totally different in a hundred years or so, it may be much nastier. There may be only factories and cars left and no more nature. You can see already that more and more electronic things and more and more factories and cars are produced. And that pollutes the environment, too. The whales change because the world has changed, and we will change, therefore, too. We should protect the whales because they are threatened by extinction. It would be stupid if they didn't exist any more, because they have such a long history behind them, and it should be continued. Maybe in another millions of years, they will be totally different again (Anna, 13 yrs.).

Anna percieves the human environment as being in constant transition. The data suggest that she has attached a symbolic meaning to the whales, a meaning that is closely related to her own anxieties and values. Against this background, the whales' fate obviously becomes a metaphor for the future of mankind. The whales symbolise for her beauty, but also continuity in a changing world and the ability to adapt successfully to new and hostile conditions. That is probably why she insists that their long (hi)story 'should be continued' (text line 24 and interview). By projecting her hopes and fears onto an animal species, Anna

creates her own, individual meaning here, using a subjectivating view of nature that is closely associated with a narrative, her story of how the whales became aquatic animals. This 'long (hi)story' of the whales, together with the author's underlying concern of a polluted and technical world, probably encouraged the symbolic meaning making process.

The social outcast motive (Max)

In contrast to the whales in Anna's story that solve their problem together, Max' account is characterized by an opposition between a single specimen that is better adapted to the amphibian or aquatic life, and the rest of the group. The existence of a deviant specimen is not only developed as to its biological, but also its social consequences, which we may call the social outcast motive. Bernd, the social outcast in Max' text, is 'teased by the other prehistoric whale kids all the time' (line 3). The story develops as the outsider successfully reproduces with a normal female (Max). It seems obvious that discrimination comes to an end as soon as the outsiders hold the majority or are the only survivors anyway. Roughly summarized, Max' story initially describes a social problem and then drives it to a biological resolution, which consists in the evolutionary triumph of the formerly discriminated social outcast. The interview data revealed interesting additional information in this case: an authentic experience had influenced Max' story. In the interview, he explains without hesitating that it was the poor fate of a discriminated girl in his class that had inspired him to write his social outcast story. Back then, he had felt for her but had not dared to help her.

> She was called Lisa. For some reason, no one else liked her, and she didn't have any friends. And so she was picked on all

> the time, although she was actually just like everyone else. At first, I had picked on her a bit, too, but then I stopped. I thought it was nasty in some way, because, if the others got bullied, they wouldn't like it either. I thought what the others did was, to be honest, crap. But I have never tried to defend her, for in that case; the others would have picked on me. (Max, 13 yrs.)

Compared to the author's authentic experience, the action of his story shows some interesting differences: Max' hero Bernd is male, and his fortune comes to a happy ending when his deviant traits prove to be advantageous and attractive for the opposite sex. It is a plausible interpretation that by writing an social outcast story with positive outcome, the author has constructed a symbolic solution for problems that had preoccupied him for quite a while.

Summary of case study findings

The explanations reconstructed from the text sample and the case studies represent different stages of conceptual development towards an understanding of natural selection. Max and other story authors stated that in order to write a non-narrative text, they would remove elements of narrative discourse and anthropomorphic attributes of the whales, or arrange the facts to a more compact account. But apart from these text features, all story authors considered their explanations to be factual and correct. This statement was confirmed by the non-narrative explanations that they formulated in the interviews.

Students used the narrative mode to create individual meaning by connecting personal experiences and values with scientific contents. Several examples of individual meaning making in student narratives could be described, two of them were unfolded in this paper. These examples suggest that some authors projected their values, hopes and fears on the biological subject, the whale ancest-

ors and their evolution. In one case, the narrative of the whales was used to valorise them and plead for their protection. The way in which these underlying affective or motivational forces influenced the author's text could be retraced in the interview. In a second case study (Max), a biographical episode could be clearly related to the story. However, in two more examples of social outcast stories, there was either no evidence for individual meaning making, or no distinct relation to the author's lived experience could be identified (Zabel 2009).

The individual meaning making was found to be of symbolic nature (Anna, Max), 'symbolic' in the sense that the individual meaning attached to the whales obviously mirrored another, formerly existing affective situation or context that could be retraced in the interview. However, the role of narrative in the described meaning making processes could hardly be derived from the student texts alone. Only in correspondence with the interview data, individual meaning making processes could be partly reconstructed.

7 Discussion and Conclusions

7.1 Why Narrative in Science Education?

Why should we use narrative in science education? And why may the 'narrative mode' influence learning results even if we do not use any narrative method? The findings of this study, as preliminary as they may be, allow to draw some prudent conclusions and dare some categorizations. Obviously, narrative can have different functions for science education:

(1) Narrative as a text form or outer shell for content

The idea that a narrative format or discourse can help to communicate scientific content is not at all new, it is a

classic and widely accepted amongst science teachers. Stories about scientists, scientific discoveries or natural phenomena can help to understand the natural world and scientific conceptions. The Swiss physics education expert Kubli (1996) makes a case for this teaching method and even extends it to the idea of the teacher being the narrator of a science lesson in a very broad sense. Within this 'narrative method', it is usually the teacher that choses the stories, and narrative is understood as a 'wrapping', a format for a scientific core content. This format is believed to enhance student motivation, and it contextualizes the naked scientific idea with historical aspects or aspects of everyday human life. Storytelling as a teaching method for the science classroom is believed to produce a beneficial 'narrative effect' (Norris et al. 2005). The results of this study, however, underline that the methodological potential and the implicit role of narrative for learning science is far from being sufficiently characterized through this 'content-core' approach. Therefore, we proceed here to more fundamental viewpoints on the role of narrative for understanding science.

(2) Narrative as a 'construal of reality'

From a constructivist perspective, narratives represent far more than just a 'format'. Bruner makes a case not to exclude narrative realities from science education. The omnipresence of stories in the human world leads him criticize the 'intolerant puritanism of 'scientific method' in the science classroom and to plead for an education that creates 'the metacognitive sensibility needed for coping with the world of narrative reality and its competing claims' (1996, p. 149). In a nutshell: science requires rational and non-narrative thinking, but as stories are so

prevalent in our world and our minds, even in the scientific culture, we cannot ban narratives from science education as mere illusions but have to train students to work consciously with both construals of reality, the narrative and the paradigmatic one.

Do our data confirm this theory, do they strengthen Bruner's approach to narrative? Using a combination of text and interview data, individual meaning making processes could be reconstructed in several cases. The role of narrative for these processes could be by assessed by retracing the narrative syntax of these texts. Furthermore, we found structural similarities between narrative and non-narrative understanding of natural selection, and the authors' lived experience. E.g.: Max and a couple of other authors developed the well-known social outcast motive to a story of a 'successful social outcast', which reflects some basic concepts of Darwin's Theory of Natural Selection. Other students used motives with lower learning potential such as: 'Threat by dangerous enemies' or 'Search for food'.

These findings allow conclusions regarding the use of narrative in the science class, against the background of an assumed narrative predisposition (Bruner 1996).

Those students who labelled their text as a 'story' indeed constructed narrative realities that correspond to Bruner's 'universals' (1996, p. 133). Their stories fall into certain genres, such as social outcast stories, and there is a problem at the centre, e.g. someone not accepted by his peers. Reasons and motives are crucial for the action, e.g. fear of being killed. The student stories even show the 'ambiguity of reference' that Bruner states: the fate of an outsider whale in the story is a fictitious event, but at the same time it fulfils its function in explaining how

the real whales evolved. So far, this evidence supports Bruner's assumption of a narrative mode. But things become more complex if we consider the heterogeneous cases, such as Anna. For her at least, the two modes were easier to combine than it could be expected according to Bruner's strict distinction.

(3) Narrative as a way of relating to natural phenomena in a symbolic and intuitive way

According to Gebhard (2003), symbolization is a prerequisite for meaningful understanding. Narratives obviously functioned as a helpful platform for this symbolization process, for some of the learners at least. Some learners' conceptions of evolution are tightly interwoven with their personal experiences and emotions. The analysis of their text and interview data revealed underlying emotions and attitudes, attached to the topic of whale evolution. In the case of Anna, it was predominantly the author's fear of environmental damage caused by modern civilization. There is an interesting contrast to Katharina's story, which was not part of this study but cited in the introduction section: the 'rhino scene' elaborates the motive of a 'struggle for life' with, thereby putting the narrator in the inferior role. In her meaning-making process, Katharina attributes a positive role to modern civilisation, associating it with protection from the former roughness of nature symbolized by the rhino. In the second case study presented here (Max), a biographical episode could be related to the story, and the happy ending of Max' successful social outcast may even be interpreted as a narrative solution to a social conflict

In all three cases cited here, the meaning that the learners created was 'symbolic' in the sense that it obviously mirrored another, formerly existing affective situ-

ation or context that could be retraced in the interview. This evidence strengthens Bruner's assumptions concerning the close relationship between narrative and individual meaning making.

7.2 Bruner's Two modes of Thought: a Critical Comment

This study is based on a constructivist perspective on narrative, because recent works, including Bruners', have revealed some universals of narrative realities that make it difficult not to consider narrative as a 'construal of reality' of its own. This seems more appropriate and more sensitive to individual learning processes than to reduce storytelling to a teaching method that benefits from a 'narrative effect' such as Norris et al. (2005) do. However, our results also allow some critical remarks on the concept of two distinct 'modes of thought'. Only a third of the interviewed authors could actually relate the scientific content of their text to certain episodes in their non-scientific, everyday life. It is possible that the teaching method did not foster narrative meaning making. Gebhard (2003) emphasises that it takes plenty of time and a certain classroom atmosphere to develop the learners' individual relation to the object of study. The occasional opportunity to write a story, integrated in an otherwise non-narrative learning environment, may not have encouraged the learners sufficiently to leave the beaten path. Also, existing relations between scientific conceptions and everyday contexts in the learners minds may have influenced the texts, but not be accessible to conscious reflection in the interview. But beside these methodological aspects, a possible explanation for these findings is that narrative meaning making is not as widespread as Bruner assumes after all – either in the science classroom, or generally in

the learner's world. Hence, we recommend that Bruner's two modes should be viewed as helpful categories in order to describe and improve learning and communicating in science education, but not be perceived as distant and mutually exclusive realms in the practice of teaching. The two modes can rather function as two extreme points on a chart, where the learners can also take intermediate positions for very different reasons. This is consistent with the findings of Baumeister & Newman (1994) and Gerrig (1994) in that it challenges the idea of a distinct 'narrative mode of thought'.

7.3 Narrative and Metaphor as Conceptual Tools for Evolution Theory

Our findings allow some conclusions on the role of narrative and metaphor imaginative thinking tools in science teaching, particularly evolution theory. The interview data provide examples of narrative meaning-making in science. Plausibly, in order to explain an event as counter-intuitive as species evolution, humans are seduced to look for an agent, for reasons and purposes, which means reasoning with the structural frame of the action schema. However, for many scientific explanations, including natural selection, this is obviously misleading, as the explanation patterns no. 1-3 show. This doesn't mean though that teachers should avoid all imaginative understanding and anthropomorphism in the science classroom. E.g., for 13 year-old learners, social outcast stories appear to be a good stepping stone to a more developed understanding of Darwinism. Student narratives, such as these social outcast stories, probably trigger meaning making

processes, or at least they make them visible. Therefore, our results encourage the use of student narratives in the science classroom.

7.4 Some General Conclusions

The following general claims on narrative in science education cannot be 'verified' in a strict sense by our results. However they are at least strengthened or inspired by the findings.

(1) Narratives, particularly those produced by the students themselves, can foster science learning, as they bridge the gap between everyday concepts and scientific conceptions. They represent one way of imaginative understanding.
(2) Nevertheless, our data do not support Bruner's assumption of two distinct and mutually exclusive modes of thought, a narrative and a scientific one.
(3) Due to their structural similarities to the scientific 'target' conceptions, some narratives are more appropriate for understanding science than others.
(4) Narratives often refer to social experiences and express values and attitudes. This can be beneficial for science learning (Gebhard 2003, Born 2007).
(5) Being able to use analogy, metaphor and narrative in order to understand and explain science is an aspect of scientific literacy, but it also bridges the gap between the 'two cultures', science and humanities.

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