Be aware of behaviour

Learning and teaching behavioural biology in secondary education

Bewust zijn van gedrag

Leren en onderwijzen van gedragsbiologie in het voortgezet onderwijs

Anco van Moolenbroek

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Leren en onderwijzen van gedragsbiologie in het voortgezet onderwijs
(met een samenvatting in het Nederlands)

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Jacobus van Moolenbroek
geboren op 31 december 1968 te Scherpenisse

Promotor: Prof. dr. K. Th. Boersma

Voor Martha

Joost, Guido & Reinder

Adaptability is probably the most distinctive characteristic of life

Hans Selye

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A teacher is not smarter than any other man is, but his ignorance is better organised.
Hardy Mertens

1 Introduction

The 21st century is called the age of biology (KNAW, 2003). In the last few decades, scientific biological research has become highly developed, bringing consequences for everyday life and influencing other scientific disciplines. This development and impact is summarized under the heading 'New Biology.' The US National Academy of Sciences, reporting about a New Biology for the 21st century, speaks about extraordinary scientific and technological advances in recent years (NRC, 2009). Nevertheless

> "…despite this potential, the challenge of advancing from identifying parts, to defining complex systems, to systems design, manipulation, and prediction is still well beyond current capabilities, and the barriers to advancement are similar at all levels from cells to ecosystems." (NRC, 2009, p. 1)

The Royal Netherlands Academy of Arts and Sciences, analysing social challenges for the life sciences and presenting a strategic foresight on New Biology, also concludes that New Biology is of great importance. Their analysis of the international position of Dutch research in biology confirms that this research is among the best in the world, particularly in disciplines such as neurobiology, cell biology, and developmental biology. Among others, New Biology can be characterized by

- the integration of sub-disciplines of biology and other scientific disciplines outside biology, such as physics and computer science;
- the involvement with complex systems, requiring a systems approach;
- a purposeful organization around the solving of real world problems.

(Eckardt, 2001; NRC, 2009; KNAW, 2011).

The emergence of New Biology indicates the need for changes in (biology) education, particularly in scientific education, and consequently, also in secondary education.

> "The New Biology represents an integrated, problem-focussed approach to science that is entirely consistent with research on how students learn best. (…) Integration information from several disciplines to study practical questions is a valuable approach at any educational level from Kindergarten on. But it is at the undergraduate and graduate levels that the New Biology both demands and presents an opportunity for new approaches. The New Biology makes it clear that biology is not only about observing and describing natural history and phenomena. Rather than teaching each level of biological organisation separately (…) a New Biology curriculum would emphasize the interconnections among those levels to understand system-level phenomena." (NRC, 2009, p. 79)

Learning and teaching New Biology requires new educational approaches to acquire knowledge of the (new) biology, competences to understand complex systems, and new strategies to learn and teach that knowledge. Therefore, the increasing social importance of biology should require innovation in biology education.

Problems in current biology education

However, it is observed that current biology education is not in line with the developments in New Biology (KNAW, 2003). In areas where knowledge is quickly outdated, it is necessary to keep the curriculum up to date. Nevertheless, outdated and irrelevant knowledge is found in current biology textbooks (AAAS, 2000).

> "The science books used in the classroom today provide a lot of facts, but they don't help children grasp the most basic concepts about the world we live in." (Budiansky, 2001, p. 1).

Although the research of AAAS is about American biology textbooks, it is supposed that the Dutch situation in education is similar (Boersma, 2001). In current biology education, three main problems are recognized (Boersma & Schermer, 2001).

1. There is an overloaded biology curriculum. It is obvious that the 21st century indicates for a great shift in the available amount of information (Friendman, 2006), and biological knowledge increases quickly.
2. The current biology curriculum conveys only minor relevance to students, even in the critical areas of personal, societal, and scientific relevance. Students have to discover for themselves the relevance of the knowledge they have to learn.
3. There is a lack of coherence in current biological knowledge. An increasing amount of information requires that students are able to articulate processes and (causal) relationships and construct coherent concepts.

To reduce these problems in biology education, a report of the Dutch Biological Council of the Royal Academy of Science and Arts recommended an innovation of biology education (KNAW, 2003). Following this recommendation, the Minister of Education established a Board for the Innovation of Biology Education (CVBO) with the task of developing new examination programmes for upper secondary biology education and to present recommendations for a learning line for students from 4-18 years of age. The Board elaborated a coherent and actual learning line for biology education (Boersma, et al., 2007), with the conviction that the so-called concept-context approach could provide an important contribution to the solution of the bottlenecks (Boersma, et al., 2005). Finally, the Board has formulated its recommendation for new examination programmes in upper secondary biology education (Boersma, Kamp, Van den Oever, & Schalk, 2010), and this advice has now been adopted by the Minister of Education. The new examination programmes will be implemented in 2013.

Evidence based education

Meanwhile, the Education Council of the Netherlands published a recommendation about the need for evidence-based education (Onderwijsraad, 2006). The Education Council defined an effective approach as one in which (1) students operate better in a cognitive, social, or other area, (2) when there are no obvious disadvantages for the function of students, and (3) there are other benefits, such as lower costs and less workload for teachers. Thus, evidence based education is about the effectiveness of new educational approaches, grounded in a view on education, or addressed to an educational problem.

The advice of the CVBO is grounded in the research program of the Freudenthal Institute for Science and Mathematics Education (FISME) at Utrecht University for the improvement or innovation of science education in upper secondary education in the Netherlands (Kuiper, Folmer, Ottevanger, &

Bruning, 2009; 2010). For biology education the program focused on the learning and teaching of genetics (Knippels, 2002), cell biology (Verhoeff, 2003), and ecosystem behaviour (Westra, 2008). In addition, other studies are elaborated on learning and teaching in chemistry (Westbroek, 2005; Prins, 2010), and physics (Klaassen, 1995; Kortland, 2001).

Behavioural biology education

This thesis is about learning and teaching behavioural biology in secondary education. Behaviour is, among all life functions, the most all-inclusive and complex expression. Consequently, behavioural biology is considered a core discipline in the New Biology with cross-links to neurobiology, evolutionary biology, and psychology (KNAW, 2011). In studying behaviour a researcher continually draws upon disciplines such as morphology, embryology and systematics, as well as that of ecology, for a more complete understanding of the phenomena with which he is concerned (Klinghammer & Fox, 1971). Bolhuis & Giraldeau (2005) describe the study of animal behaviour as an area that ranges from molecules and neurons to individuals and populations. Therefore, behavioural biology education should actually emphasise the use of systems thinking competence in order to interconnect among the levels of biological organization in order to understand systems-level phenomena in behaviour. Therefore, behaviour is considered a biological key concept that is relevant for learning about biological thinking (Boersma & Schermer, 2001). Biological thinking is defined as the competence to think like a biologist and, among others, embraces dispositions such as form-function thinking, systems thinking, and evolutionary thinking (Boersma & Schermer, 2001).

Furthermore, the societal relevance of behavioural biology appears from its contribution to animal welfare, the conservation of species and the understanding of human nature (Bolhuis & Giraldeau, 2005). Therefore, accurate observation and description of behaviour contribute to the study of domesticated animals, and not only biology and psychology students should be taught behaviour, also to veterinary, animal science, wildlife, sociology, and anthropology students (Klinghammer & Fox, 1971).

Despite its importance, it appears that behavioural biology in Dutch secondary education is largely outdated (Van Moolenbroek, Boersma, & Waarlo, 2005), and that students are not aware of behaviour (Van Moolenbroek, Boersma, & Waarlo, 2007). In addition, scientific research on behavioural biology education is including educational practice and students' understanding of behaviour, is scarcely available.

Current didactical strategies for genetics (Knippels, 2002), cell biology (Verhoeff, 2003), and ecology (Westra, 2008) are domain-specific, although components such as the concept-context approach and the problem posing approach could be useful for a learning and teaching strategy (LT-strategy) for behavioural biology as well. In addition, LT-strategies for genetics and cell biology focus on structures. The behaviour of populations in ecosystems has been described with mathematical equations, with the emphasis on modelling. Less attention was paid to the development of a dynamic systems concept.

In contrast, explanation of behavioural change and adaptation are central notions for an LT-strategy for behaviour. Consequently, learning and teaching the dynamic and complex nature of behaviour requires a domain-specific strategy. However, an adequate LT-strategy for behavioural biology is not yet available.

As we described before, a concept-context approach is considered as meeting the three main problems in current biology education. However, a strategy for the use of successive contexts in education is not available. Therefore, the challenge of behavioural biology education is to develop a learning and teaching strategy (LT-strategy) wherein students acquire an understanding of the dynamic and complex nature of behaviour, both in their own lives, and in the lives of other organisms. In order to meet this challenge, we formulate the following research question:

> What are the characteristics of an adequate learning and teaching strategy for behavioural biology in secondary education that increases students' awareness of behaviour?

Design research

Every teacher should be interested in the effectiveness of his/her teaching, and wonder what could be improved in his/her teaching. However, teaching also presumes learners. Therefore, teachers should focus on both learning and teaching. Learning and teaching processes are influenced by a broad range of factors. 'Abiotic' factors influence the classroom climate, such as temperature, (day) light, available space, and time (of the day, of the year). 'Biotic' factors influence the interaction between students and teacher, and the students themselves.

Actually, we examine behaviour in the classroom. In this thesis, we will argue for behaviour as the outcome of a dynamic and complex system. It is difficult to investigate complex learning and teaching processes, for example, the relation between teacher behaviour and students' results (Martens, 2010). Additionally, the main possibility to improve education is through increasing the professionalism of the teacher (Wiliam, 2010). It is the profession of a teacher to motivate his students, and therefore, an understanding of LT-processes is a necessary condition for effective teaching. Good instruments, such as textbooks, technology, and the competences to use them, could contribute to the effectiveness of the LT-process.

Nevertheless, in the Netherlands, most teachers do not have access to systematic research on the effectiveness of their teaching, and, researching is another discipline. However, because of its relevance for teachers and students, educational research should join the educational practice. In the words of Schoenfeld (1999, p. 8):

> "Educational research has evolved to the point where it is possible, much of the time, to conduct research in contexts that are of practical importance, working on problems whose solutions help make things better *and* contribute to theoretical understanding. Finding and working on such problems is a high leverage strategy for making a difference in the years to come."

However, the nature of the relationship between theory and practice of teaching and learning is the subject of an on-going discourse (Jörg, Davis, & Nickmans, 2007). The many different learning theories demonstrate the complexity of the educational practice (Woolfolk, 2007). The educational practice can be considered as a complex system that requires specific conditions for teaching methods to be effective and a thorough knowledge of learning processes (Jacobson & Wilensky, 2006).

Consequently, educational research is complicated, and new knowledge should be developed in interaction between theory and practice (diSessa & Cobb, 2004).
Additionally, the increasing knowledge about the working of the brain provides new insights for teaching and learning processes, such as Sousa states:

> "Teachers try to change the human brain every day. The more they know about how it learns, the more successful they can be. (…) There is a growing interest among educators in the biology of learning and how much an individual's environment can affect the growth and development of the brain." (Sousa, 2006, p. 3)

Therefore, in addition to an innovation of the biology curriculum and classroom practice, there also is a need for an innovation of the educational system itself (Schoenfeld, 1999; Burkhardt & Schoenfeld, 2003). In particular, the practice of educational curriculum innovation should be based on educational research. Shymansky & Kyle (1992) formulates four assumptions for educational research:

1. The *process* of curriculum reform should be investigated.
2. Research should be *for* educational reform, not *about* educational reform. It should unify (not separate) the work of educational theorizing and practice.
3. Research should contribute to *improving* curriculum, instruction, and assessment.
4. Science curriculum reform and curriculum reform research should *transform* schools and classrooms.

Being a principal of a secondary school, we consider the increasing professionalism of the team of teachers to be a matter of urgency. In addition, leading a team or teaching a class is influencing behaviour. That is the reason for our fascination for educational research: to improve the educational practice, particularly for the practice of biology education. It is for that reason that the research for an adequate LT-strategy for behavioural biology could only be done by design research. Design research provides insight into learning in classrooms by using well-structured instructional interventions (Joseph, 2004), and interaction between research, design and pedagogical practice.

Outline of this thesis

This thesis is built up with the following components. An LT-strategy is founded on our view on learning and teaching that is described in chapter 2. Two educational approaches will be integrated, and the chapter ends with a set of design criteria for an LT-strategy.

In chapter 3 we elaborate the methodology of the developmental research approach. Before we describe the exploration phase and the empirical phase, we argue for a justification of the used research methods.

Chapter 4 describes 21st century behavioural biology, followed by the elaboration of the implications for biology education. The exploration results in a supplement of the set of design criteria for an LT-strategy.

The current and desired educational practices are explored in chapter 5. From some prior studies, we learned that current state of behavioural biology in Dutch secondary education is not suitable for teaching 21st century behaviour, and we argue for an approach for innovation of behavioural biology education.

In chapter 6, we construct an LT-strategy for behavioural biology, taking into account the formulated design criteria. From the LT-strategy, a scenario for testing in the classroom is described.

The scenario is tested in two subsequent research cycles, and chapter 7 focuses on the instruments and methods used in the empirical research phase.

To create an overview, an outline of the intended and executed scenario in the research cycles is described in chapter 8. Chapter 9 provides for the analysis of students' conceptualization of the concept BEHAVIOUR.

Finally, in chapter 10, we answer the research question and review the design criteria. Furthermore, we discuss two implications: the role of the teacher and systems thinking in an LT-strategy for behavioural biology.

There is nothing more practical than a good theory

Kurt Lewin

2 View on learning and teaching

2.1 Introduction

Over ten years of teaching biology, we developed our own intuitive ideas about learning and teaching processes. These ideas are based on what worked in the classroom. After designing our own lessons and materials, we then tested these in the classroom and modified them after reflection. In addition to the commercially available biology teaching materials, we developed learning materials for our students, and discovered that they want to be actively involved in their learning processes. In order to create active learners and enhance their motivation, we let them collaborate or role-play by using both fictional and real situations. Designing lesson materials we asked ourselves: what should students learn, why should they do this and how could they do this effectively? What, why and how. 'What' is the quest to acquire knowledge. 'Why' asks for motivation, meaning, and justification. 'How' examines characteristics of teaching and learning processes.

Today, education often focuses only on 'learning to learn', which is a strategic approach, because it deals with learning strategies. The question 'how to learn' is salient: what can be learned if we do not know how to learn? However, the answer to the question 'why should we learn this' gives students understanding and insight in the curriculum. Therefore, 'learning to think' is a more fundamental approach, because of its more lasting impact. 'Learning to think' helps people to survive.

Three keywords are important in our view on learning and teaching. First, education should be focused on the development of the *independence* of students. They must 'learn to think' and second, therefore ought to be challenged to be *active* in their own learning processes, changing knowledge from available to useful or functional (Van Parreren, 1990; Van Oers, 2006). Thinking also appeals to *imagination*, which is in our view the third keyword. An image may say more than a thousand words, even if the image is painted by words. Narratives (stories) trigger the attention and emotions of students and lead to their involvement. A story can also be understood as a personal representation of a real, authentic social practice that is relevant for students.

Besides the question how to create active, motivated students, there is also the question if our way of teaching is effective in promoting the learning of our students. During this Ph.D. research a more founded view on learning and teaching was developed. In this chapter, we will explore how the aforementioned view is phrased in learning theories and we will argue for approaches that could be used to learn the biology of behaviour. In section 2.2 we will argue that acquiring knowledge is above all, the construction of useful knowledge in one's mind. Therefore, we adopt the cultural historical activity theory. Section 2.3 exposes why learning has to be meaningful. Finally, in section 2.4 we will conclude which implications these findings may have for a learning and teaching strategy and introduce two approaches: the concept context approach, and the problem posing approach.

2.2 Acquiring knowledge

There are several theories about how people acquire knowledge and the view on learning is linked with the view on the nature of knowledge (Mayer, 2002). Since classical antiquity philosophers, such as Socrates and Aristotle, became thoughtful about the nature of knowledge. Socrates distinguished knowledge as episteme from knowledge as phronesis (Doornenbal, 2005). Knowledge as episteme means the

> "objective, conceptual, general knowledge, transferred by a specialist" (Doornenbal, 2005, p. 28).

Episteme is cognitive knowledge, free of acting, attitude, and personality. According to Socrates, episteme is only a semblance of knowledge and wisdom, not the thing itself. Knowledge in the sense of phronesis stands for practical wisdom or practical knowledge. Doornenbal (2005, p. 39) describes phronesis as

> "knowledge that is reflected in someone's acting and which supposes self-knowledge and the ability of (critical) self-reflection."

Phronesis focuses on understanding of specific, concrete circumstances and complex, ambiguous situations. Generally, one important difference in the characteristic of knowledge as episteme and phronesis could be seen in the role of activity. Episteme is free of acting, while phronesis is reflected in someone's acting. Thus, knowledge as episteme is seen as objective; it is learned free of context. In phronesis knowledge is always connected with activity and therefore to the activity context. It has a subjective nature.

Even today, these types of knowledge are distinguished. Van Parreren (1990) distinguishes rote knowledge from functional knowledge. Rote knowledge is devoid of meaning or understanding. Rote knowledge can easily be reproduced, and is obtained by memorisation or repetition. It is imprinted. Functional knowledge functions in a different context than that in which it has been learnt.

What kind of knowledge has to be learnt and taught? The question is not which knowledge is superior, but rather which contributes most to students' development. It is clear that knowledge that can be used in different circumstances and contexts is the most helpful type for developing students' independence; this is functional knowledge that has meaning and is used. Nevertheless, it does not mean that rote knowledge is unworthy of being learned. Functional knowledge cannot exist without rote knowledge. Obviously, an arbiter in a football match needs rote knowledge above all, because the speed of the game. A physician, conversely, cannot retain all the existing medical knowledge that there is, and usually he has enough time to find out what he needs to know.

Sometimes, functional knowledge is described as meaningful knowledge and seen as the opposite of rote knowledge (Mayer, 2002; Birgerstam, 2002), but it is more fruitful to conceive rote-meaningful as a continuum (Novak, 1977), because knowledge always has more or less meaning for someone. Thus, the question is when knowledge has meaning for a learner? ‘When’ indicates for a process or for conditions. In this reasoning, a learning process is a process of meaning making in relation to our own experiences (Mayer, 2002; Birgerstam, 2002). Meaningful learning requires relevant knowledge and emotional commitment (Birgerstam, 2002; Novak & Cañas, 2008). Meaningful learning occurs when students acquire knowledge and cognitive processes needed for successful problem solving. (Mayer, 2002). Meaningful learning requires prior knowledge, because learning is a process in which new information is related to an existing relevant aspect of an individual's knowledge structure (Novak, 1977). Experiences, commitment, and prior knowledge all point to the context-bound nature of knowledge and the need for acting. Acting could also be defined as the capability of problem solving.

Summarizing, we distinguish two dimensions of knowledge. A dimension based on relevance or usefulness in contexts and a dimension based on the degree of acting (see figure 1). Relevance can be seen as a *condition* for and acting as a *process* of meaning making.

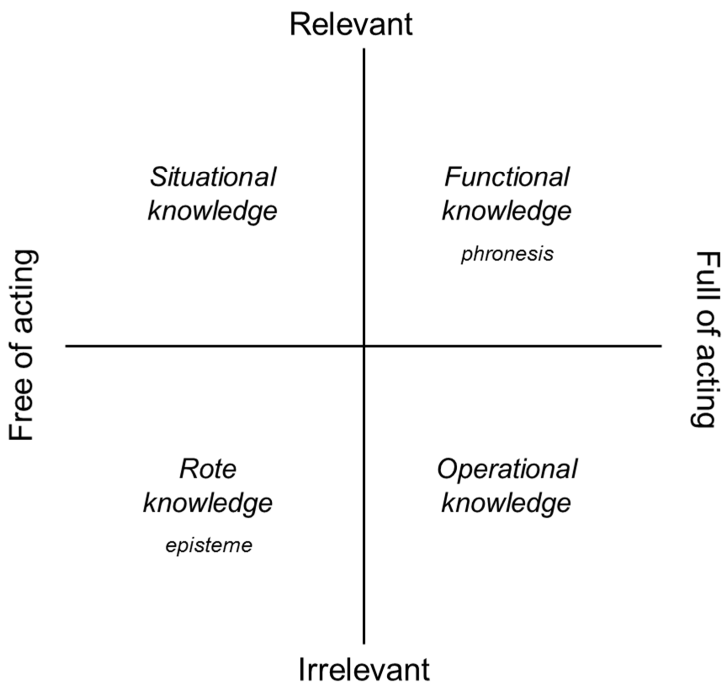


Figure 1. Knowledge characterised by the degrees of relevance and acting.

Furthermore, in figure 1, we also distinguish situational and operational knowledge. Situational knowledge is specific to a particular situation, and mostly acquired by experiences (Conway & Bekerian, 1987; Savelsbergh, De Jong, & Ferguson-Hessler, 2002). We define operational knowledge as the knowledge that is required to execute a task, mostly acquired by exercise. Knowing how to control a machine is an example of operational knowledge.

Since knowledge is the outcome of learning processes, it is necessary to examine learning processes. Mayer (2002, p. 227) writes that

> “a focus on meaningful learning is consistent with the view of learning as knowledge construction in which students seek to make sense of their experiences. (…) In contrast, a focus on rote learning is consistent with the view of learning as knowledge acquisition in which students seek to add new information to their memories."

Meaningful learning occurs when experiences cause a change in an individual's knowledge or behaviour (Mayer, 2002; Woolfolk, 2007). Therefore, it is recognized as an important educational goal. The human brain continually reorganizes itself because of the input. Teachers try to change the human brain every day (Sousa, 2006). Learning is the outcome of interaction (Kirschner, 2006). Biologically, organisms learn in interaction with stressors (see more in chapter 4). In short, experiences in contexts are salient conditions for learning and thus, learning requires a social practice within which students are invited to perform all kind of activities. Practitioners of such a social practice use knowledge in activities that are constitutive for that practice.

Recent research on learning and remembering suggests a bottleneck between acquiring new knowledge and remembering prior knowledge. The brain cannot do both at the same time, which supports the idea that learning rote knowledge is not contributing sufficiently to the students' cognitive development (Huijbers, Pennartz, Cabeza, & Daselaar, 2009). In line with the argument that functional knowledge is most helpful for the development of students' independence, we argue that learning has to be meaningful for the learner to acquire functional knowledge.

Current educational performance

Since functional knowledge contributes most to the development of students, education should be focused on that type of learning. However, what is the actual educational practice in classroom? Brooks & Brooks (1993) note five characteristics of current practice in the classroom. First, classrooms are dominated by teacher talk. Second, teachers rely heavily on textbooks. Third, students work in relative isolation on tasks that require low-level skills, rather than higher-order reasoning. Fourth, student thinking is devalued in most classrooms because teachers do not challenge students to think, but rather want to discover whether students know the right answers. Fifth, there is a premised notion that a fixed world exists that the learner must come to know. Although they describe the American situation, its relevance for the Dutch practice can be recognised.

In the Netherlands there have been several efforts to let students learn more independently (so called 'studiehuis'), but this is primarily stimulated by the limitation of student-teacher contact time. Klop & Boersma (2008) noted in a case study of the differences between traditional and innovatory biology education that more conventional teachers want to make knowledge relevant, but due to a lack of time, this desire moves easily to the background. Therefore, the students' question why they have to learn something demonstrates that they do not see the relevance of the curriculum. Many teachers are chained by the curriculum, and

> "many students struggle to understand concepts in isolation, to learn parts without seeing wholes, to make connections where they see only disparity, and to accept as reality what their perception questions." (Brooks & Brooks, 1993, p. 7)

Lipman (1988) notes the transmission of knowledge and cultivation of wisdom as the two principal aims of education. He also remarks that tradition-bound societies emphasise the first aim. Knowledge then is

> "thought of as a body of eternal verities, perennially applicable to an unchanging world" (Lipman, 1988, p. 1),

where in contrast, this world is actually complex (Birgerstam, 2002). Generally, the emphasis of the current teaching practice is on knowledge as episteme, the transfer of objective knowledge, with little understanding and activity by students.

What can be the reason for this emphasis? Behaviorism is still firmly attached to the current educational system. It describes human behaviour by the stimulus-response relation coupled with positive or negative reinforcement. Many times students see learning as an achievement instead of a development. They learn for the test. Another influence on education is the philosophy of logical positivism, also called logical empiricism. This is a "philosophy asserting the primacy of observation in assessing the truth of statements of fact and holding that metaphysical and subjective arguments not based on observable data are meaningless."[1] See here again the emphasis on facts, on rote knowledge. Van Aalsvoort (2004a; 2004b) analysed the lack of relevance in chemistry education for students in secondary education and argued that logical positivism currently ignores the relation between science and society.

Nevertheless, times change. Research about learning processes, brain development, and the abundant availability of information makes is necessary to reflect on what is usage in education and what is the effectiveness of learning and teaching. During the seventies and eighties of the last century, educational research showed a change from behaviorism to another view on knowledge acquisition: constructivism (Boersma, 1995). Constructivism is a philosophical position that views knowledge as the outcome of experience mediated by one's own prior knowledge and the experience of others. It is a much-used approach in the spectrum of learning theories, with a wide palette of meanings. Brooks & Brooks (1993) formulated guiding principles of constructivism. Education is based on (1) posing problems of emerging relevance to students, (2) structuring learning around primary concepts, (3) seeking and valuing students' points of view, (4) adapting curriculum to address students' suppositions and (5) assessing student learning in the context of teaching.

In this respect, learning would be considered as an *active* process that only takes place when learners are actively engaged in learning; as a *constructive* process, because learners have to connect new knowledge with their prior knowledge to construct meaning. Furthermore, in the constructivist view, learning is a *self-regulated* process, whereby learners have to regulate and control their learning process on their own. A next characteristic is that learning is considered as a *situated* process, because it is always linked to a specific situation and context, in which learning takes place, and as a *social* process, because knowledge is always constructed in interaction with other people. Finally, learning is considered as an *emotional* process, because learning only takes place when learners are motivated and in a good mood to learn (Reinmann & Mandl, 2006). From these characteristics of constructivist learning processes, it could be concluded that learning and teaching processes should be learner-centred. From the notion that learning is a self-regulated process, it could be concluded that learning is a strictly personal and conscious process.

We have two objections to constructivism as defined by Brooks & Brooks (1993). First, self-regulated learning requires both will and skill (Montalva & Torres, 2004) and one cannot expect students to regulate these just needs by themselves, because the development of children is usually triggered by the acts of adults. Learning is interaction, and it is questionable whether it is a conscious process.

The second objection is the proposed role of the teacher. The role of teaching in constructivist learning processes is generally seen as a facilitator (Vighnarajah, Luan, & Bakar, 2008), and learning is not

[1] Source: Logical positivism. (n.d.). The American Heritage® Dictionary of the English Language, Fourth Edition. (Retrieved February 2012, from http://www.answers.com/topic/logical-positivism)

discovering more, but rather interpreting through a different scheme or structure (Fosnot, 1993). We disagree. Learners must be able to participate in practices. The British philosopher, Herbert Spencer, stated that the great aim of education is not knowledge but action. Therefore, cognitive development must be directed instead of being followed or facilitated. The learner needs an expert: knowledge should be made relevant and meaningful by the teacher. In sum, the role of the teacher is underexposed in constructivist learning processes as mentioned above.

The cultural historical activity theory

For a theoretical underpinning of our view on learning and teaching that combines constructivism with a directive role for the teacher, we adopt the cultural historical activity theory. This theory solves the problem of the missing teacher role in the characteristics of the constructivist learning process we have sketched above.

The psychologist Lev Vygotsky (1896–1934) supposed that the cognitive development of a child should be directed. In his cultural-historical activity theory, an expert is important for the development of children. Shortly before he died, Vygotsky formulated his cultural historical activity theory (CHAT). Vygotsky assumed that

> "every function in the child's cultural development appears twice: first, between people (interpsychologically) and then inside the child (intrapsychologically). This applies equally to voluntary attention, to logical memory, and to the formation of ideas. All the higher functions originate as actual relationships between individuals." (Vygotsky, 1978, p. 57).

Vygotsky's theory embraces the following three basic principles:

1. Learning processes require interaction between human beings and their environments. An individual lives in communities, and the development of an individual, including the cognitive, is stimulated by relationships. *Social interaction* plays a fundamental role in the development of cognition.

2. Cognitive development is enhanced when people work in their *Zone of Proximal Development* (ZPD). To reach the ZPD, and to support them as they are learning new things, children need the help of adults or more competent individuals.

> "The zone of proximal development of a child is the difference between his actual developmental level determined by independent problem solving and his potential developmental level determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1935, p. 42)

Simply stated, the cognitive operations that a student can complete with the assistance of someone else today, he or she can accomplish alone tomorrow.

3. Cognitive development is led by *actions*. Actions can be mental actions: thoughts and words. Language is the vehicle for bringing thoughts from one person to another. Development is directed by the *dialogue*, but once concepts have been learned, there is only an internal monologue. This is called the process of *internalization*. In contrast to Piaget, Vygotsky maintained that the child's external self-focused speech during activities did not disappear. Instead, through a dialectical transformation, inner speech guided the child's planning and other emerging thought processes. To recapitulate, children

obtain their cognitive skills by imitation of adults or a more competent peer in their neighbourhood, in their culture.

2.3 Motivation and meaning

In addition to the abovementioned principles, Vygotsky considered that a child has an intrinsic drive to learn. Deci & Ryan (1985) postulate human beings as active organisms with innate tendencies toward psychological growth and development, a development that is related to the environment:

> "The social environment in which they attempt to satisfy their basic needs, suggests that the degree of basic psychological need satisfaction influences development, performance, and well-being." (Deci & Ryan, 2000, p. 263)

Ryan & Deci (2000a) studied the phenomenon of motivation and developed the Self-Determination Theory (SDT). The SDT maintains that the understanding of human motivation requires a consideration of innate psychological needs for competence, autonomy, and relatedness. Motivation is not something given by a teacher, but it emerges when these needs were satisfied. Ryan & Deci (2000b) distinguish the level and orientation of motivation, how much and what type of motivation respectively. Orientation of motivation answers the question why someone acts. A motivated student, will not ask why he has to do some task, but finds it necessary to know something (Westbroek, 2004) or sees the usefulness of what he is learning (Bransford, Brown, & Cocking, 2000; Sousa, 2006).
The SDT describes two types of motivation: intrinsic and extrinsic. Intrinsic motivation is

> "the tendency to seek out novelty and challenges, to extend and exercise one's capacity, to explore and to learn" (Ryan & Deci, 2000a, p. 70)

With extrinsic motivation, environmental factors outside the performer tend to act. Intrinsically motivated people have more interest, excitement and confidence, which in turn are manifested as enhanced performance, persistence and creativity, as compared with persons who are extrinsically motivated. Another difference between in- and extrinsic motivation is the goal of the drive. Extrinsically motivated people perform an activity to attain an outcome and intrinsically motivated people are satisfied by the activity itself. Ryan & Deci (2000b, p. 60) note that

> "given that many of the educational activities prescribed in schools are not designed to be intrinsically interesting, a central question concerns how to motivate students to value and self-regulate such activities, and without external pressure, to carry them out on their own."

Extrinsic motivation is usually characterized as an impoverished form of motivation, but it can also be an important force, and

> "knowing how to promote more active and volitional forms of extrinsic motivation becomes an essential strategy for successful teaching." (Ryan & Deci, 2000b, p. 55).

The SDT supposes that there are various types of extrinsic motivation, varying in the degree of self-determination, and people who internalize external factors have internal reasons for action (internal perceived locus of causality). Internalization refers to people's active attempts to transform an extrinsic motive into personally endorsed values and thus assimilate behavioural regulations that were originally external (Ryan R. , 1995; Ryan & Deci, 2000a).

> "With increasing internalization and its sense of personal commitment come greater persistence, more positive self-perception, and better quality of engagement." (Ryan & Deci, 2000b, p. 61).

Internalization is facilitated by the psychological needs of relatedness, autonomy, and competence. Motivation is enhanced when one need is accompanied with the other needs. Relatedness – the need to feel connectedness with others – is most important for internalization. Autonomy is the feeling of volition that can accompany any act. Studies have shown that increasing autonomous extrinsic motivation was associated with more engagement, better performance, lower dropout, higher quality learning and better teacher ratings (Ryan & Deci, 2000a). Internalization is a function of perceived competence, also called self-efficacy. People are more likely to participate in activities when they feel efficacious with respect to those activities (Ryan & Deci, 2000a).

Several similarities between the SDT and the CHAT can be noticed. Both theories emphasise social interaction and environmental or cultural factors, facilitating cognitive development and (intrinsic) motivation. According to Vygotsky, internalization is the internal reconstruction of an external operation and is clearly a central issue in childhood socialization. In the SDT, internalization is continually relevant for the regulation of behaviour across the life span (Ryan & Deci, 2000a). The three psychological needs that facilitate internalization also have similarity with terms of the CHAT. Autonomy could be compared with "voluntary attention," the willingness to act. Relatedness relates to emotions and the need for social interaction with experts and the context. The relationship between learning, emotion and body state runs much deeper than many educators realize. Decision-making is also an emotional process, making meaning and allowing people to respond appropriately in different contexts (Mortimer & Scott, 2003; Immordino-Yang & Damasio, 2007). Relatedness is not only necessary for the transfer of knowledge, but teacher encouragements also increase intrinsic motivation (Ryan & Deci, 2000a). Competence could be related to the zone of proximal development (ZPD). The ZPD embodies a concept of readiness to learn that emphasises upper levels of competence. Competence, as mentioned in the SDT, is when one feels capable to solve a problem independently. Reaching the level of actual development means that new knowledge must be connected to prior knowledge and experiences of students. It also means that new knowledge has to make sense and meaning, because it is related to relevant concepts students already know. Consequently, motivation and meaning are mutually linked: the need to act and the need to know. Meaningfulness then is the essence of the need to act and the need to know.

Furthermore, social interaction supposes a social practice. Figure 2 shows the relation between an individual and a practice, between the need to act and the need to know. An individual has to gain relevant or useful knowledge to participate in a practice. When new, relevant information is linked to prior knowledge, it becomes meaningful (Novak, 1977), and the individual's cognitive structure is changed. To participate in the practice, an individual has to interact, and these actions are necessary to maintain the social structure of the practice. The motivation to know emerges from the need to act, when knowledge lowers the threshold for acting.

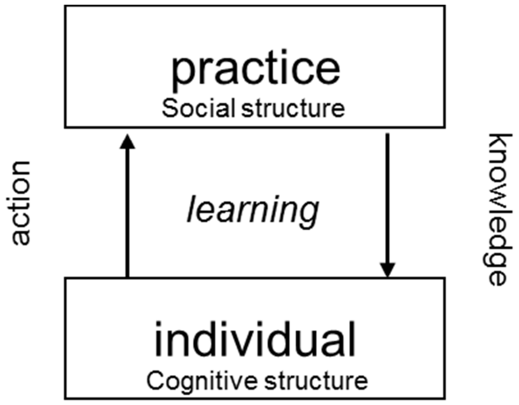


Figure 2. Interaction between an individual and a practice.

While the CHAT gives a mind-set of how cognitive development takes place by interaction with an expert, the SDT gives insight into the underlying attitudes and goals that give rise to action.

2.4 Implications for a learning and teaching strategy

Design criteria for an LT-strategy could be developed from both theories. We distinguish three building blocks for an LT-strategy. An LT-strategy should include the use of contexts, emphasise conceptual relations within contexts, and evoke a need to act. These three components are closely interconnected, but have different goals.

The use of contexts

A school context diverges in several ways from the contexts of real life. Kneppers, Van Boxtel & Van Hout-Wolters (2009) write that it is important to understand situations outside school where students can function in order to give concepts meaning. They emphasise the importance of a context for learning. Among others, Brown, Collins & Duguid (1989) noticed that students need much more than abstract concepts. They emphasise the need for students to be exposed to authentic activities with the use of domain specific conceptual tools. In the words of Immordino-Yang & Damasio (2007, p. 9):

> "Simply having the knowledge does not imply that a student will be able to use it advantageously outside of school".

A context is understood here as a recognizable social practice wherein people need knowledge to act (Boersma, et al., 2007) and according to Vygotsky's CHAT the context determines the meaning of a concept (Van Aalsvoort, 2004b). A context could also be understood as a narrative (Bruner, 2003), and contributes therefore to the motivation of students (Whitelegg & Malcolm, 1999; Pilot & Bulte, 2006).

The execution of authentic activities in authentic contexts to teach concepts instead of learning concepts by teaching contexts is a condition for meaningful learning and constructivist learning environments are also appropriated to relate science to socio-scientific issues (Pilot & Bulte, 2006). Because of their complexity, contexts have to be suitable for education and a conceptual framework is necessary to describe concepts in relation to each other, determined by their role in acting in a context.

Interaction

According to the CHAT, learning is the outcome of an activity, the interaction between a person and its environment, and the outcome of a narrative process (Van Oers, 2006; 2006a). Interaction can be understood at several levels. In the research programme of the Langeveld Institute for the Study of Education and Development in Childhood and Adolescence at Utrecht University, three types of interaction are distinguished (Kirschner, 2006). First, considering the interaction between learner and teacher, effective education requires interaction between teacher and students (Van Parreren, 2005). As mentioned before, a learner needs an expert and the attitude of the teacher with respect to the students is quintessential.

> "A dominant teacher, for example can expect to elicit obedient student behaviour and a friendly teacher can expect to elicit a pleasant student reaction." (Kirschner, 2006, p. 10).

The second type is the interaction between equivalent learners. Kneppels, Van Boxtel & Van Hout-Wolters (2009) conclude that problem solving in real life is an activity done by people together, but in school situations learners generally learn alone. Therefore, opportunities for social interaction will trigger students' involvement with the curriculum. Bransford, Brown & Cocking (2000) note that people must work collaboratively and share their knowledge and that students are motivated when what they are learning has an impact on others. The third type is the interaction between learners and artefacts/tools. Curricula should be designed to emphasise the interaction between learners and their learning task (Dahms, et al., 2007), connecting pupil's out-of-school experiences to classroom education (Uitto, Juuti, Lavonen, & Meisalo, 2006). Huit (2004) stresses the important role of physical sensation as a starting point for human learning. Information must be registered as sensation to be available for processing in the brain: the relation between 'head and heart'. In addition to these three types, a fourth type of interaction can be noted, namely that of a learner with oneself. New knowledge must interact with the learner's cognitive structure; therefore, a learning task should be situated in the students' ZPD. This would be reached by evoking motives.

Evoking motives

A third difference between school life and real life is abstract thinking in contrast to reasoning. (Bransford, Brown, & Cocking, 2000; Kneppels, Van Boxtel, & Van Hout-Wolters, 2009). Reasoning is acquiring a reason for motion, in other words getting a motive. Van Aalsvoort (2004b) cites a twofold function of a motive, namely a cognitive and an emotional one.

> "As a derivative of the object with its properties, it directs and organizes activity. As a characteristic of the subject with its needs, it has the function of exciting activity. (…) Whereas a need only excites, a motive directs and organizes activity as well." (Van Aalsvoort, 2004b, p. 1637).

We cannot be clever without questions. Thinking is driven by questions and social practices should be designed in such a manner that they utilize students' critical thinking skills while their thought processes are being challenged and new knowledge is gained (Dahms, et al., 2007). Therefore, motives should be evoked by asking the right questions, and reflection on motives should stimulate new questions. In other words, the design generates the desired questions for students and the motives must be in a logical sequence.

From building blocks to an educational model

In the Netherlands, large-scale innovation of the curricula of chemistry, physics, mathematics and biology has been launched over the last decade. This innovation was triggered by four problems: curriculum overload, lack of coherence, lack of relevance for students and insufficient transfer (Boersma, 2001; Boersma & Schermer, 2001). These problems are noticed in other countries as well (Fratt, 2002; Gilbert, 2006).

Two approaches are used in Dutch developmental research to explore the question how to get an adequate learning and teaching strategy, in order to address the problems mentioned above. These approaches can be associated with the building blocks named previously in this section. First, along with the remarks on getting motives, we describe the problem posing approach:

> "a programmatic view of the possibilities for improving science educational practice at a content-specific level" (Klaassen, 1995, p. 88).

The second approach is called the concept-context approach, which, is meant in particular as a model for the selection of concepts for learning science, but can also be used as an educational model. Therefore, we integrate these two approaches.

2.4.1 Problem posing approach

The problem posing approach has been developed and elaborated at the Freudenthal Institute for Science and Mathematics Education (FIsme) and has been elaborated in several theses with the aim of involving students actively in their learning process (Klaassen, 1995; Vollebregt, 1998; Kortland, 2001; Knippels, 2002; Westbroek, 2004; Schalk, 2006; Westra, 2008, Prins, 2010). The problem posing approach could be summarized as

> "bringing students to such a position that they themselves come to see the point of extending their existing conceptual resources, experimental base and belief system (with accompanying changes of meaning) in a certain direction" (Klaassen, 1995, p. 111).

The aim of the problem posing approach is that students know why they do something in any stage of the learning process, in other words they have a motive to learn.

> "The emphasis of a problem posing approach is thus on bringing students to such a position that they themselves come to experience a content-related sense of purpose and come to see the point of extending their existing conceptual knowledge and experiences in a certain direction, i.e. in the direction of the concepts to be taught." (Lijnse, 2005, p. 19).

Lijnse (2005) distinguishes *having a motive* for doing something and *being motivated* to do it. A content related motive directs students' thoughts and may lead to internalization of external motivation (see section 2.3). Two essential ingredients of the problem posing approach are the construction of *global* and *local* motives. A global motive stimulates students to learn the topic and it gives them some insight into what is coming. A global motive could be a central steering question, which is answered at the end of the lessons. It would be evoked when the topic could be related to the interest of students or by showing its relevance for them. Local motives must lead to participation in the next learning activity. Building a motive could be compared with the use of an advanced organizer (Ausubel, 1960; Novak, 1977), because it provides anchorage in cognitive structure.

The problem posing approach assumes that the students' prior knowledge is largely correct. Correct prior knowledge and everyday life experiences form a common ground for a starting point (Lijnse, 2007). Learning and teaching activities are based on the prior knowledge of students and their own questions (motives), structured by the teacher (Kortland, 2001). Therefore, the role of the teacher is crucial, because the teacher brings students to such a situation by applying activities that they cannot perform without help. It is necessary to find equilibrium between autonomy and guidance.

In the problem posing approach, a sequence of interrelated learning and teaching activities forms the structure of a design of the learning and teaching process. Varying with the focus of the strategy, five or six phases are distinguished (Klaassen, 1995; Kortland, 2001; Bulte, Westbroek, Van Rens, & Pilot, 2004; Westra, 2008). In reflection on the problem posing approach Lijnse quotes (2005, p. 21) the following phasing.

> Questioning
>
> Phase 1. Orienting and evoking a global interest in and motive for a study of the topic at hand.
>
> Phase 2. Narrowing down this global motive to a content-specific knowledge-need
>
> Activity
>
> Phase 3. Extending students' existing knowledge in view of the global motive and the more specifically formulated knowledge-need
>
> Phase 4. Applying this knowledge in situations for which the knowledge was meant
>
> Reflection
>
> Phase 5. Creating, by reflecting on the developed knowledge, a need for a theoretical orientation.
>
> Phase 6. Developing further theoretical knowledge within this orientation.

Lijnse (2005) notes that phase 2 and 5 represent one of the main points of a problem posing approach, namely the creation of relevant needs. This makes the problem posing approach different from other learning cycle models, such as 5E (Bybee, et al., 2006), for teaching science from a constructivistic view. 5E stands for five stages in a learning cycle: engage, explore, explain, elaborate and evaluate. Whereas, for example, the 5E model lets students explore ideas, the problem posing approach allows students to explore activities in a context in the sense of a socio-cultural practice.

Since knowledge strongly connected to a context, it may obstruct transfer, and consequently abstraction is required. (Bransford, Brown, & Cocking, 2000). The reflection phase provides this and, coincidentally, serves at the same times to develop a new motive. The question remains whether knowledge in one context developed according to the problem posing approach can be used in another context. This process is indicated as recontextualisation (Boersma, et al., 2007) and will be explained in the next section.

2.4.2 Concept-context approach

Approximately eight years after the development of the problem posing approach, educational research was started at the Freudenthal Institute for Science and Mathematics Education at Utrecht University on the so-called concept-context approach to improve science education.

According to Gilbert (2006) the use of *contexts* could reduce the curriculum load. Van der Zande (2011), however, found that the use of context could result in additional extracurricular concepts that imply an overloaded biology curriculum. However, for all things the concept-context approach is an approach that is intended for the choice of learning goals and organizing knowledge (Boersma, et al., 2007). The concept-context approach has also educational implications, because of the close connection between context and concepts and, according to Vygotsky's CHAT, the learning process is the result of the interaction between the learner and his environment (Van Oers, 2006a; Kirschner, 2006). Contexts have a dual function: relating scientific concepts to contexts and improving the relevance of the science curriculum by selecting contexts having relevance for the students (Boersma, et al., 2007).

Definitions of a context are quite divergent. Literature shows contexts seen from a positivistic perspective or from a situative perspective (Van Aalsvoort, 2004a; 2004b), where scientific knowledge is considered independently from or respectively embedded in contexts. According the CHAT a learning theory and the definition of context are related: a context is seen as a social practice where scientific knowledge is embedded in the performance of the *activity* (Boersma, et al., 2007).

Boersma et al. (2005) argue that understanding a context as a social practice is most appropriate for the choice of practice for education, because of its characteristics. A social practice is constituted by one or more cultural historical defined *activities*, providing for the *need* of its participants.

> "In social practices participants perform goal-directed activities, using knowledge, symbols, language, tools, and sharing meanings and values." (Westra, 2008, p. 29).

The *activity* is the central notions in the CHAT and is defined as the physical and mental actions, executed by a person interacting with another person or organism (Boersma, et al., 2007). Examples of activities are observing, researching, choosing, and taking care for.

According to Vygotsky, a *concept* emerges and takes shape in the course of a complex interaction aimed at the solution of a problem, so a concept is an active part of the intellectual process. Vygotsky stated that direct teaching of concepts is impossible and a waste of time. Concepts are tools for thoughts and control one's activities (Vygotsky, 1934; Wellings, 2003; Dahms, et al., 2007). In the concept-context approach a concept is explained as an important idea of biology, with which relevant specific knowledge can be connected (Boersma, et al., 2005). Knowledge is context-bound, with the consequence that the meaning of a concept may differ from one context to another. The situated nature of scientific knowledge means that knowledge cannot simply be applied in other social practices. Another implication of the situated nature of scientific knowledge is that one cannot speak about misconceptions, because of the fact that the meaning of a concept may scientifically wrong, but appropriate in a non-scientific social practice. This also typifies the close relation between context and concepts.

Since knowledge is embedded in activities, and therefore situational, its relevance differs from one practice to another, depending on the object, the activities and the context. Considering a context as a social practice implies that practices can be characterized by several parameters, such as goal, instruments, nature of knowledge, and language (Van Eijk, Goedhart, Kaper, & Ellermeijer, 2004). Boersma et al (2005; 2007) use two criteria to categorize practices, namely, the motives for and nature of knowledge production. Based on the aim of a context and the use of (biological) knowledge in it, they distinguish three types of practices: life-world practices, professional practices and scientific practices. Life-world practices are practices like families and sport clubs, while practices like laboratory, physiotherapy, and garden centres are professional practices. Examples of scientific practices are ecological and behavioural research.

Difference in relevance of knowledge signifies the necessity to generalize the meaning of concepts. Wellings (2003), considering the interaction of spontaneous and scientific concepts in the development of higher mental processes, describes this process from a Vygotskian point of view (see figure 3). Spontaneous concepts are developed in every-day-life learning, beginning in concrete phenomena, while scientific concepts are developed in school learning. Integration of the spontaneous concepts and the scientific concepts only evokes when education occurs in students' Zone of Proximal Development.

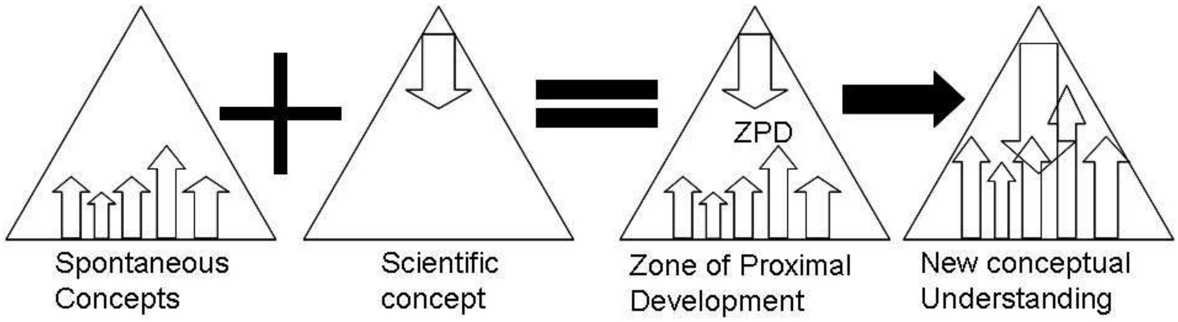


Figure 3. Interaction between spontaneous and scientific concepts. (Adapted from Wellings, 2003)

The new conceptual understanding appears in the use of the concept in another practice. Students are only able to use the acquired concepts if they can use them in a variety of contexts. Therefore, students have to adapt the meaning of a concept: this process is called recontextualisation (Van Oers, 1998b; 2001).

For example, the term STRESS has several meanings (Keil, 2004). In a life-world practice, daily life learning, it could be described as mental strain or emotional pressure. Commonly, it has a negative connotation and is sometimes seen as a state and in other times as a process. In a medical context, stress is essentially the rate of wear and tear in the body (Selye, 1978). In mechanics, stress is the force on an object. From this highly different sense, it is clear that generalizing of the concept STRESS as a state of tension, caused by environmental stimuli (stressors) will be necessary, but for learning it is not enough to transfer the concept from one practice to another. By transferring the term stress to another practice, one has to change the meaning of the term, without losing sight of generalization.

Literature about learning considers transfer as the capability of a student to apply what was learned in new situations and to learn related information more quickly. (Bransford, Brown, & Cocking, 2000;

Sousa, 2006; Woolfolk, 2007). In that case, transfer is a static, measurable process. However, where the meaning of a concept may differ from practice to practice, it is difficult to speak about the degree of transfer as a criterion for the outcome of the learning process. Therefore, the concept transfer misses the mutual relation between the learner and the activity and in recent literature based on socio-cultural learning the term 'transition' is used (Beach, 1999; Van Oers, 1998). Transition implies activity and changes the relation between a learner and a social activity. Transition is the capability of a student to adapt his or her understanding to participate in another practice, which requires recontextualisation. In the concept-context approach, transition is induced by teaching concepts in different social practices.

2.4.3 Integration of the two models

Integrating the concept-context approach with the problem posing approach, needs interpreting contexts from the cultural-historical view as social practices where activities are (made) meaningful for students. Integration of the problem posing approach in the concept-context approach is illustrated in figure 4. The starting point for each LT-activity is a problem or question raised by students and induced by the teaching process, the central steering question. All learning activities should contribute to the answer to the central steering questing, which guides an activity in a social practice.

Reflection on an LT-activity has to promote transition of the learned concepts and this process takes place both within a context and between contexts.

The teacher plays an important role in the process of inauguration in a social practice. He or she has to be the expert and has to bring spontaneous and scientific concepts together, so that students construct new understandings and will be able to act.

2.5 Design criteria for a learning and teaching strategy

The design of the learning and teaching strategy for behavioural biology education will be based on design criteria. In this section, we will summarize the educational design criteria as underpinned in the above sections, particularly section 2.4.

1. An LT-strategy for behavioural biology should be based on behavioural biology concepts used in authentic *social practices*, which means existing in social reality. The behavioural biology concepts should be elaborated and students should have the opportunity to explore their personal, societal and/or scientific relevance.

2. Participation in a social practice motivates learning as the outcome of *interaction* between a person and his/her environment. An LT-strategy for behavioural biology must promote interaction between learners and their learning environment in an educationally appropriate social practice.

3. Learning activities must promote the thinking processes of students. Therefore, an LT-strategy for behavioural biology must evoke *motives* or one or more steering questions. The sequence of LT activities must provide a storyline and create opportunities for non-interrupted learning.

4. *Recontextualising* of earlier acquired concepts is not self-evident when other practices are introduced, and should be incorporated explicitly in the LT-strategy. This implies that an LT-strategy should consist of more than one practice.

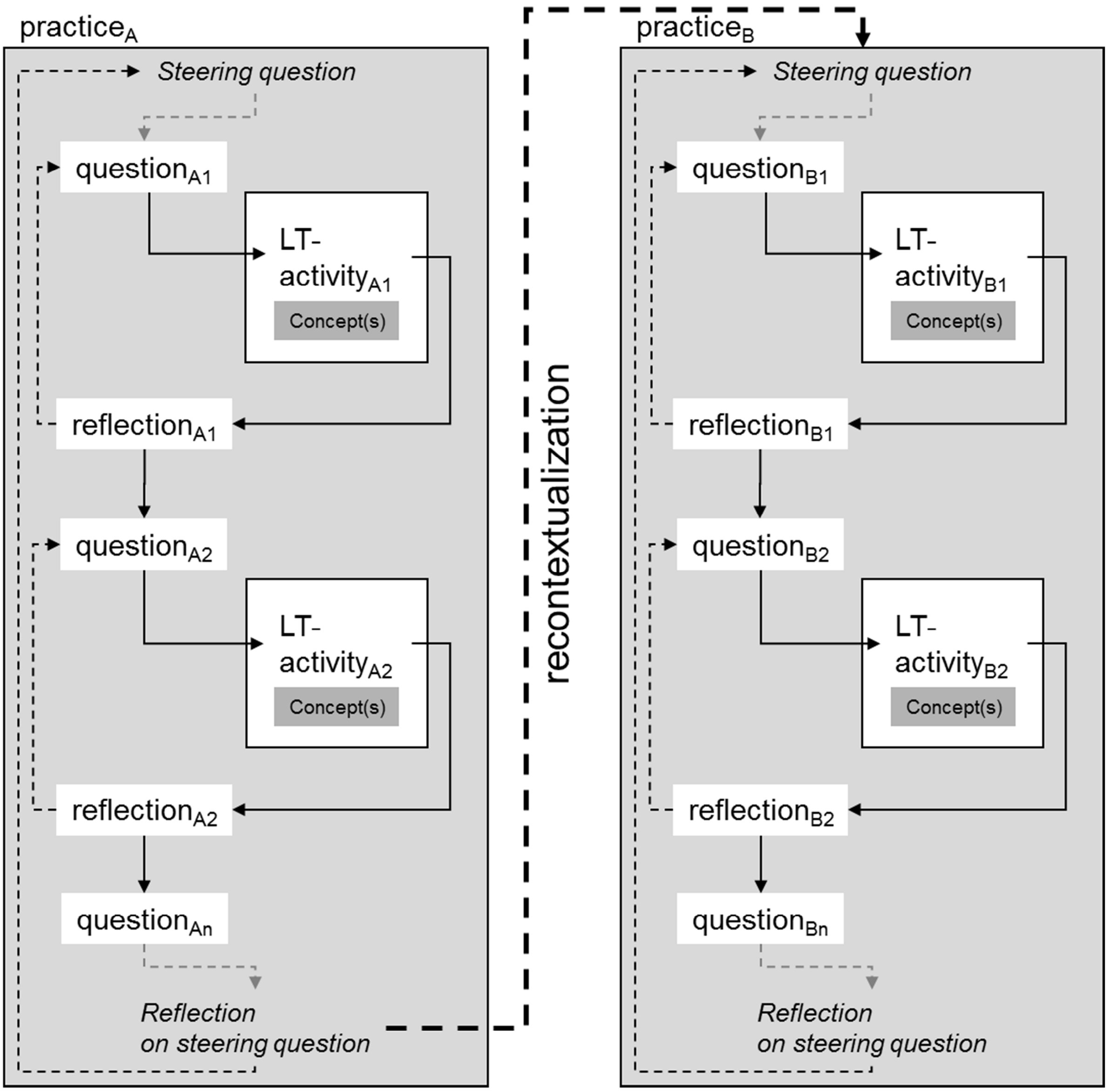


Figure 4. Integration of the concept-context approach and the problem posing approach.

3 Developmental research approach

3.1 Introduction

The aim of this study is to develop an adequate and evidence based LT-strategy for behavioural biology in upper secondary biology education. In chapter 2, we described the theoretical underpinning of an adequate learning and teaching strategy, combining the problem posing approach with the concept-context approach. The next step is to develop an LT-strategy that could adequately be used within the educational practice. Therefore, we need an adequate research method.

Because of our view on learning and teaching that learning is the construction of meaning, elicited by interaction, an LT-strategy must be investigated within real educational practice. However, because of its dynamic and complex nature, investigating educational practice is not easy. In essence, an adequate LT-strategy should contribute to the improvement of educational practice. Therefore, the design of an adequate LT-strategy should be developed in interaction with the educational practice in the classroom.

In educational research, a developmental research approach is used if solutions for complex educational problems are required (Van den Akker, 2003; Boersma, Knippels, & Waarlo, 2005). Nowadays, developmental research is also called design research, because it provides insight into learning in classrooms by using well-structured instructional interventions (Joseph, 2004), and interaction between research, design and pedagogical practice. In section 3.2, we will describe the general characteristics of the design research approach, and in section 3.3, we describe the use of this approach for this study.

3.2 Design research

Developmental or design research knows several names and approaches. In an overview article about design research, Edelson (2002) notes the differences between the traditional and the contemporary roles of design research. Whereas the traditional role consists of the test of an educational theory, nowadays design research is a process in which design plays a critical role in the development of theories for educational design (Boersma & Waarlo, 2009). Traditional research mainly focuses on descriptive knowledge, while developmental research focuses on prescriptive knowledge (Van den Akker, 1999). However, design experiments are developed as a way to carry out formative research to test and refine educational designs based on principles derived from prior research (Collins, Joseph, & Bielaczyc, 2004). They are approached by instructional interventions to provide understanding and improvement of learning in real-world practice, intertwining research, design, and pedagogical practice (Joseph, 2004; Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006). The emphasis is on justifying educational design theory, instead of developing educational materials, such as with curriculum development. Developmental research is necessary because of the difference between an intended curriculum (‘in vitro’) and an executed curriculum (‘in vivo’), wherein the learning environment plays a distinctive and influential role (Letschert, 2004; McKenney, Nieveen, & Van den Akker, 2006). Just the interplay between educational theory and practice makes educational research difficult (Martens, 2007). Developmental research is aimed to solve complex problems in educational practice (Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006), by investigating both the characteristics of the interventions and the processes of designing and developing the interventions (Plomp, 2010).

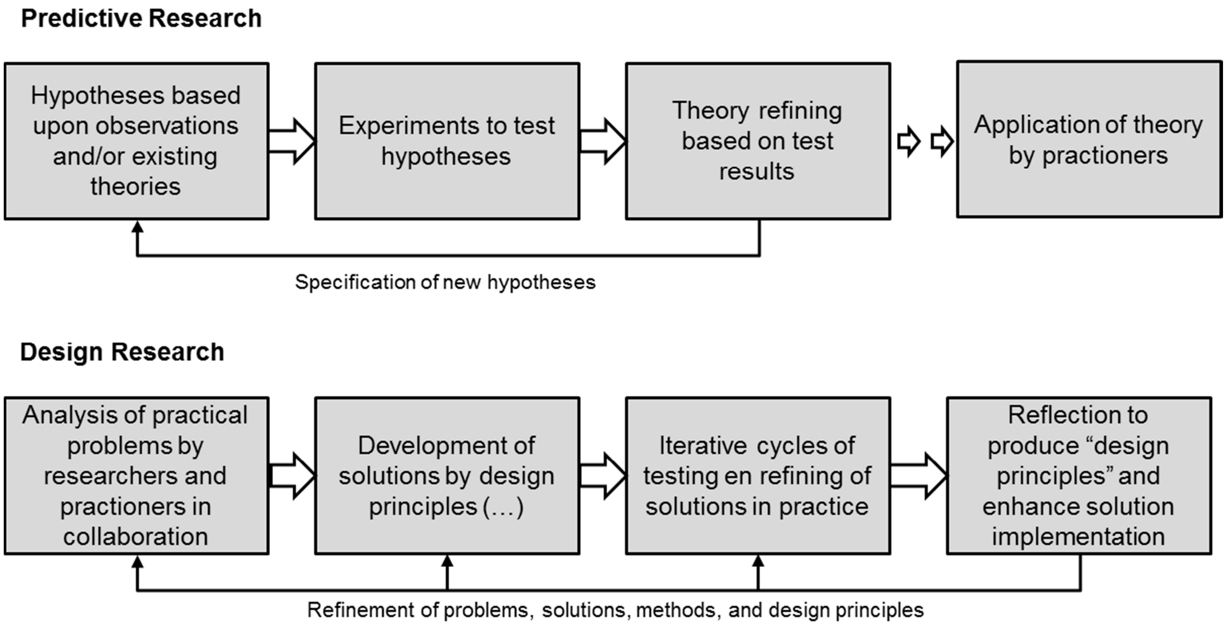


Figure 5. Predictive and design research approaches in educational research (after: Reeves, 2006, p. 59).

Figure 5 shows a schematic view of the different approaches of predictive and design research. An important characteristic of design research is that it eliminates the boundary between design and research, whereby the design process is considered as a learning process (Edelson, 2002). Design research methodologies are relatively new, and a domain-specific language is developing (Kelly, 2004). A challenge of educational design research is to characterize the complexity and solidity of the design in a way that will be valuable for others (Barab & Squire, 2004). Cobb, Confery, diSessa & Lehrer (2003) identified five characteristics of design experiments.

1. The aim of design experiments is to develop theories about both the learning process and the materials and approaches that are designed to support that learning. Therefore, developmental research focuses on the process, whereby it is attempted to understand why certain interventions work.

2. Design research methods are highly interventionistic, and therefore suitable for testing innovations. Nevertheless, design research is strongly supported by and connected to prior research, and guided by research goals (Edelson, 2002). Instructional interventions are designed with explicit theoretical grounding (Burkhardt & Schoenfeld, 2003). A design researcher might hypothesize that a certain kind of representation (intervention) will help learners to develop knowledge about a particular idea or that a certain activity structure will motivate learners in a particular way (Joseph, 2004; Collins, Joseph, & Bielaczyc, 2004).

3. Design experiments always have both a prospective and a reflective side. On the prospective side, designs are based on a hypothesized teaching and learning process. In developmental research,

researchers begin with a set of hypotheses and principles that they use to guide a design process. Importantly, these hypotheses and principles are not detailed enough to determine every decision. On the reflective side, design experiments are conjecture-driven, and during the research process, data analyses from several perspectives lead to new sharpened conjectures. In conducting a retrospective analysis, extensive longitudinal data sets are generated during an experiment.

4. Design experiments have iterative cycles of design. As conjectures are generated, tested and sharpened, new conjectures are developed and tested. The result is an iterative process featuring cycles of invention and revision. The design researchers proceed through iterative cycles of design and implementation, using each implementation as an opportunity to collect data to inform subsequent design.

> "Through a parallel and retrospective process of reflection upon the design and its outcomes, the design researchers elaborate upon their initial hypotheses and principles, refining, adding, and discarding – gradually knitting together a coherent theory that reflects their understanding of the design experience." (Edelson, 2002, p. 106)

5. Theories developed during the experimental process are humble not merely in the sense that they are concerned with domain-specific learning processes, but also because they are accountable to the activity of design. The theory must really work, and the critical question must be asked whether the theory informs prospective design, and if so, in what way. Therefore, the outcome is directly concerned with the problems addressed by the practitioners, and the design involves researchers in the improvement of education.

3.3 Outline of the research design

For two decades, the developmental research plan that we use in this thesis has been in use by researchers of the Freudenthal Institute for Science and Mathematics Education of Utrecht University. The research plan of this study is structured in two phases: an explorative phase and a cyclic research phase (figure 6).

Explorative phase

In the explorative phase, explorative research is executed in order to determine the domain-specific learning and teaching problems. Furthermore, to build a theoretical foundation of learning and teaching, an articulated view on general educational theories and educational practice is developed by studying literature. The explorative phase results in a domain-specific philosophy of learning and teaching and in building blocks for an LT-strategy, which is expressed in chapter 2.

In this study we analysed the content of Dutch biology textbooks on behavioural biology in secondary education together with the current state of the art of behavioural biology. This elaboration was aimed to define possible difficulties and problems in behavioural biology education. First, ideas of concepts in behavioural biology that should be taught were collected. After that, research was done to gain insight in the ideas of students about behaviour, identifying prior knowledge, and collecting educational building blocks for an LT-strategy for behavioural biology (chapter 4 and 5). The domain-specific philosophy of learning and teaching, the acquired insights in the students' ideas, and the behavioural biology concepts to be selected all yielded design criteria for an adequate LT-strategy for behavioural biology education.

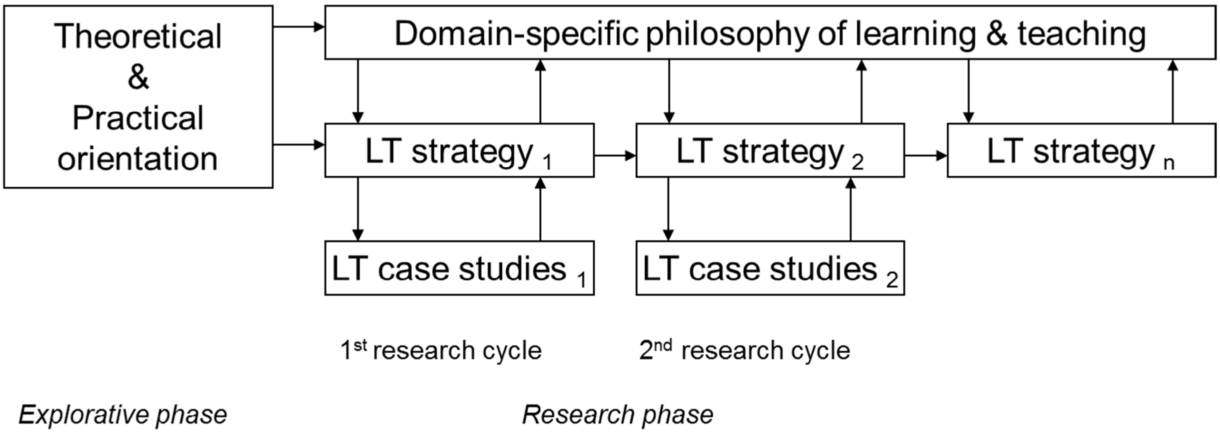


Figure 6. Design of developmental research (from: Boersma, Knippels, Verhoeff, Waarlo, & Van Weelie, 2002), consisting of an explorative phase and a cyclic research phase. An LT-strategy is tested in two or more subsequent research cycles, which result in a domain specific educational theory.

Cyclic research phase

In the research phase, the design criteria were operationalized in a cyclic process of design, field-testing in case studies, reflection on the design, and revision of the design. The research cycles were planned until development no longer resulted in further improvement of the LT-strategy. Generally, two or three cycles are sufficient to develop a final LT-strategy. A complete cycle is shown in detail in figure 7.

The data and literature collected in the explorative phase, and the view on learning and teaching, result in design criteria and learning objectives. A first LT-strategy is designed (chapter 6), and following the problem posing approach a sequence of problems is elaborated in a sequence of learning and teaching activities. The problems are presented in a logical way for students, corresponding to the findings of the explorative phase.

The LT-strategy is elaborated into a scenario that describes the LT-activities of the teacher and students. A scenario predicts and theoretically justifies in detail the teaching–learning process as it is expected to take place and why it is expected to happen in that way (Lijnse & Klaassen, 2004). This process is described in chapter 6. Simultaneously and in interaction with the scenario, lesson materials were constructed.

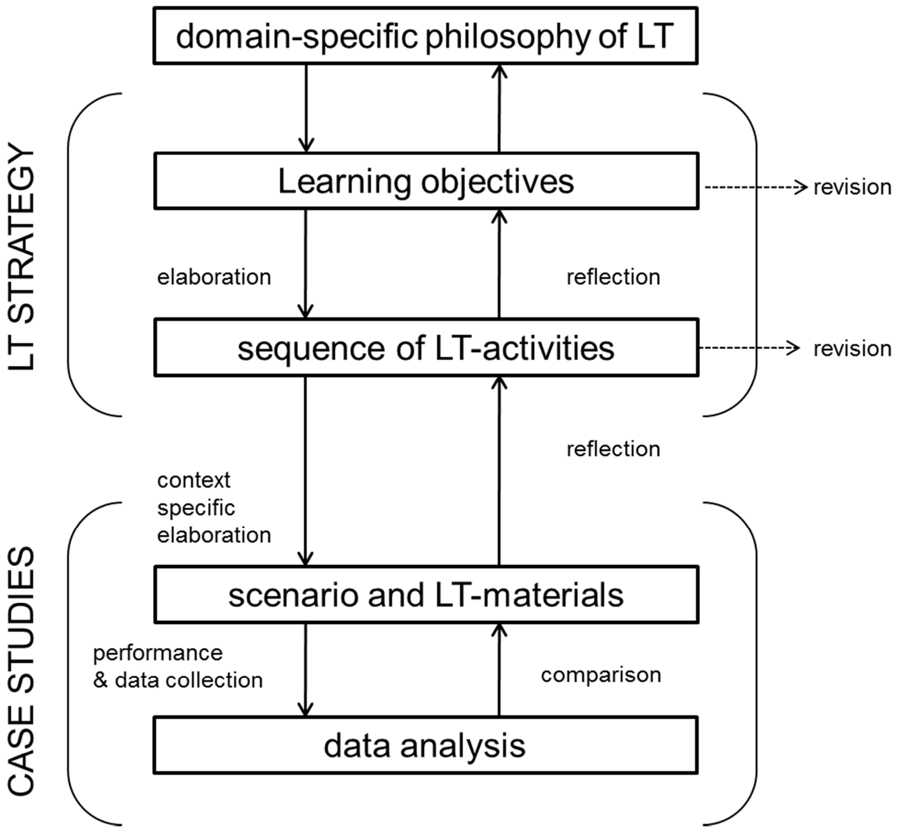


Figure 7. Detailed research cycle of the developmental research approach. The boxes show a (sequence) of products, while the arrows sign for activities. Adapted from Knippels (2002).

With the scenario and the lesson materials, the LT-strategy is empirically validated in real teaching practice (chapter 7). With the help of the data sets that are collected from the test phase the executed scenario is compared with the intended version, providing for a revision of the scenario (chapter 8), the learning materials, and the LT-strategy. Thereafter, a new research cycle is elaborated. Finally, with the data of the last (second) research cycle, students' conceptualization is reconstructed (chapter 9) and a final design is proposed, the research question is answered, and in reflection on the design process new theoretical insights on educational design are articulated (chapter 10).

We would expect that this research on an adequate LT-strategy for behavioural biology delivers design clues for the use of social practices, and the introduction of the systems thinking competence.

4 Conceptualizing 'behaviour'

4.1 Introduction

Behaviour is inherent to organisms. Each organism behaves and people in our society have a great interest in the scientific backgrounds of behaviour. In addition to philosophy and ethics, psychology and sociology are involved with this topic[2]. Behaviour is a key biological concept (Van Caulil, 2001; Kamp & Boersma, 2001), and is studied in ethology. Ethology may be described as the biological discipline of the behaviour of humans and animals (Baerends et al, 1973), or as the biological study of behaviour (Tinbergen, 1963).

Nowadays many scientists prefer the term 'behavioural biology' instead of ethology, because the study of behaviour also includes new research disciplines such as neurobiology and cognitive psychology (Bolhuis, 2002; Bolhuis & Giraldeau, 2005). In section 4.2, we give an overview of 21st century behavioural biology. First, we discuss the definition of behaviour and the current disciplines of behavioural biology. The multidisciplinary character of behavioural biology raises the question of what is the science of behaviour. Therefore, the last part of the section reviews how behavioural biology is structured according to Tinbergen's four questions and which concepts belong to these questions.

The discussion on current behavioural biology evokes the question of what concepts must be taught in secondary biology education. In section 4.3, we will indicate the implications for education and a resultant set of design criteria for an LT-strategy on behavioural biology.

4.2 21st century behavioural biology

Definition and disciplines of behaviour

Although it might seem easy to define the concept of behaviour, it appears that behavioural biologists do not agree on what constitutes behaviour (Levitis, Lidicker, & Freund, 2009). Levitis *et al*. (2009) note that many textbooks assume that the reader knows what is meant. For example, Campbell & Reece (2005) describe behaviour in their study book as 'what an animal does and how it does it.' This definition seems to be clear, but as Levitis *et al*. (2009) argue, it does not meet the criteria for scientific correctness: operational, essential, widely applicable and succinct. Based on a consensus of views of behavioural biologists, Levitis *et al*. (2009) formulate the following, more precise definition of behaviour:

Behaviour is defined as "*the internally coordinated responses (actions or inactions) of whole living organisms (individuals or groups) to internal and/or external stimuli, excluding responses more easily understood as developmental changes.*" (Levitis, Lidicker, & Freund, 2009, p. 6).

[2] A survey with the Biosis Previews – behavioral sciences – journal list and the Thomson Reuters Master Journal List JOURNAL LIST with the search words behaviour and behavior results in a list of more than hundred different scientific journals.

This definition justifies three conclusions. First, with the emphasis on stimuli, causality is an important aspect of behaviour. Behaviour is described as a complex phenomenon, which emerges not by one cause but by a combination of internal and external causes. Second, behaviour is reserved to whole organisms, while the additions 'internal' and '(individuals or groups)' signify a distinction in levels of biological organization. Third, there is always behaviour; inaction (e.g. freeze) is also behaviour.

If behaviour is reserved to the whole organism, the question must be discussed if plants (and protozoa) do show behaviour or not. Taking account of this definition of behaviour, the question can be answered affirmatively. Silvertown & Gordon (1989) have defined plant behaviour as the response to internal and external signals, and noted that the language of animal behaviour is being used increasingly to describe plant activities, such as foraging and habitat choice. Trewavas (2003; 2009) considers intelligence[3], similarities in learning, communication and memory between plants and animals in discussing aspects of plant behaviour. He concludes that in terms of complexity of signalling and problem solving within their own environmental context, plants lack nothing compared with animals in skill and behavioural complexity. However, following the boundaries of the contemporary scientific disciplines regarding behaviour, in this thesis we will consider behaviour as animal behaviour, with connections to human behaviour.

In the afore mentioned definition of behaviour developmental processes are excluded, because in general such modifications are relatively slower than phenomena considered as behaviour and they are primarily based on ontogenetic programs, although they are influenced by internal and external stimuli (Levitis, Lidicker, & Freund, 2009). Moreover, this does not mean that developmental processes as explanation for behaviour are excluded, but the definition answers the question of what behaviour is, while an explanation answers why behaviour arises.

The question of explanations of behaviour is investigated in behavioural biology. Behavioural biology is a relatively young but major discipline within biology, with its roots in ethology. In the nineteen thirties Konrad Lorenz and Niko Tinbergen laid the basis for ethology. On the occasion of Lorenz' 60th birthday in 1963 Tinbergen published an article "On aims and methods of Ethology", which still has authority (Bolhuis, 2002) and which was recently reprinted in the book "Tinbergen's legacy" (Bolhuis & Verhulst, 2009). In this article Tinbergen demonstrates the close affinity between ethology and the other disciplines of biology and states that the 'no man's land' between ethology and neurophysiology in the meantime will be invaded from both sides, consequently with mutual influence. He argues that all branches of science that that pay attention to aspects of behaviour should come together within 'Behavioural Biology'.

Indeed, the current state of behavioural research shows that boundaries between the different branches of behavioural biology increasingly match each other. Thanks to new techniques, especially in molecular biology and brain investigation, new opportunities for integrated research approaches in behavioural biology arise (Bateson, 2003), delivering more understanding of the role of genes in the occurrence of behaviour (Joosse, 2001). New interdisciplinary research fields, such as neuroethology, behavioural endocrinology and behavioural genetics, have become fields in their own right (Hogan, 2009).

[3] Intelligence is described by Trewavas (2009) as the capacity for problem solving and is seen as a whole organism property.

Today, much attention is paid to the functioning of the brain in relation to learning processes and their influence on behaviour, resulting e.g. in the discipline of educational neuroscience[4], the release of a new journal Mind, Brain and Education, and research programs about the brain, cognition and behaviour at several universities. Finally, without being complete, Hogan & Bolhuis (2009b) report that the relation between ethology and psychology has become closer since the publication of Tinbergen's paper. Therefore, Bolhuis (2002) argues for a broad view in behavioural biology research: not only ethology, but also disciplines as neurobiology and cognitive psychology are included in behavioural biology. Table 1 gives an overview of the current disciplines and shows that behavioural biology is wider than ethology.[5]

Table 1. Main disciplines of current behavioural biology, based on Bolhuis & Giraldeau (2005), Klapwijk (2005), Fraser & Weary (2005) and Hogan (2009).

Disciplines	Description
Neuroethology (or neurobiology) and cognitive neuroscience	Studies the mechanisms of the brain and nervous system, which are the neuro-physiological basis for behaviour.
Behavioural ecology	Addresses the function of behaviour. During the last decades the attention shifted from socio-biology, which interprets social behaviour in the light of evolution, to optimality theories, which try to answer the question how natural and sexual selection could be responsible for behaviour patterns, and then to predict these.
Cognitive ecology	Studies the relation of an animal's ability to collect and process information in relation to its ecology. Examples are the diversity in birdsong and the question if having a food store has a selective pressure on spatial memory.
Applied research on animal behaviour	Seeks the solution of practical problems, arising from the use of animals, or addresses the prevention of undesirable animal behaviour. Research on the welfare of animals is aimed at designing better accommodation for animals in confinement, on the farm and in the laboratory.

Concepts of behavioural biology

Tinbergen wrote in the aforementioned article that

> "there is no consistent 'public image' of ethology among outsiders; and worse: ethologists themselves differ widely in their opinions of what their science is about." (Tinbergen, 1963, p. 410).

Therefore, the confusion about the definition of behaviour and the multidisciplinary character of behavioural biology evokes the question of what the science of behaviour is about. What are the 'big questions'?

The big question people ask when they observe behaviour is: "Why does it do this?" which is the question about the explanation of behaviour. Tinbergen (1963) believed that the following four questions should be asked about the natural behaviour of any animal:

- What triggers the behaviour?
- How does the behaviour develop?

[4] http://www.brainandlearning.eu/ (Retrieved February 2012)

[5] See also appendix A: Overview of scientific disciplines studying behaviour.

- What is it for?
- How did the behaviour evolve?

Respectively, these questions are about the *causes*, the *development* or ontogeny, the *function* and the *evolution* of behaviour[6]. Tinbergen states that answering these four questions would lead to a much deeper understanding of behaviour, although there is considerable overlap between the four questions. Even today this distinction in types of explanations is seen as one of Tinbergen's most lasting contributions to the study of behaviour (Bolhuis, 2002; Sherry, 2009) and the questions have served as a useful framework for many researchers in the field of behavioural biology, because

> "you cannot understand animal behavior if you do not also understand the meaning of Tinbergen's four questions." (Hogan & Bolhuis, 2009a, p. 26).

Evolution of behaviour often depends on mechanisms of behaviour and the development of behaviour is essentially a causal problem, but has also functional aspects (Bolhuis & Giraldeau, 2005). Although causes and development are merged into the ‘mechanisms of behaviour’, a clear distinction between these issues in scientific research is necessary (Bolhuis, 2002).

The first ethologists, Tinbergen, Lorenz, and Von Frisch dealt particularly with the causes of behaviour, while they focused on observing the behaviour of animals in their natural environment. In the nineteen seventies, ethology was dominated by the functional question, significantly influenced by the publication of Wilson's book ‘Sociobiology’ (1975). In this period, emphasis was laid on evolutionary explanations of behaviour, at the expense of the mechanism of behaviour. Since that time, because of the multidisciplinary character of the causal question, attention to the mechanism of behaviour has increased.

The abovementioned spectacular developments in the field of animal behaviour do evoke the need for a comprehensive survey of the concepts used in behavioural biology. The book “The Behavior of Animals, Mechanisms, Function, and Evolution”, written by twenty prominent scientists in the contemporary disciplines of behavioural biology, represents the current state of behavioural studies (Bolhuis & Giraldeau, 2005). The book has three main parts: Mechanisms of Behavior, Function and Evolution of Behavior, and Animal Behavior and Human Society. These sections correspond to the questions of Tinbergen and are partially concerned with the relevance of research on animal behaviour in our everyday lives. Below, we will present a short overview of the most important topics and concepts.

Mechanisms of behaviour: causation & ontogeny

Causation is the immediate effect of external and internal factors on the occurrence of behaviour (Hogan & Bolhuis, 2009a). Tinbergen (1963), analysing the causation of behaviour, refers to Lorenz' three statements about behaviour. First, just as an organism has physiological characteristics, it has behavioural characteristics. Second, even in its relatively simple form, behaviour is more complex

[6] The four questions are derived from the three major problems in Biology, formulated by Huxley (1942): “mechanical-physiological” (causation), “adaptive-functional” (survival) and “historical” (evolution). Tinbergen added the fourth question about ontogeny. Nowadays, these four questions also have authority in other biological research (Medicus, 2005).

than the types of movements usually studied by physiologists. Third, behaviour is controlled by internal factors, more than most physiologists believed at that time.

Within behaviour patterns and systems could be distinguished. Systems and patterns presuppose structure and need activation. The structure of a behavioural mechanism is formed by systems of perception, processing and motor activity or mechanism, while the activation of these systems is given by stimuli. Perceptual mechanisms analyse incoming sensory information and solve the problem of stimulus recognition. The motor mechanisms coordinate the neural output to the muscles, which results in recognizable patterns of movement. The central mechanisms coordinate the perceptual and motor mechanisms, and provide the basis for an animal's mood or internal state (Hogan, 2009). Figure 8 is a schematic representation of the structure of a behaviour system. For the sake of clarity, we retained the connections between perceptual and motor mechanisms.

The complexity of behaviour increases with the amount of behaviour systems involved in that behaviour, and their interactions. This stresses the second statement of Lorenz that even in its simple form behaviour is vastly more complex than the types of movements usually studied by physiologists (Tinbergen, 1963).

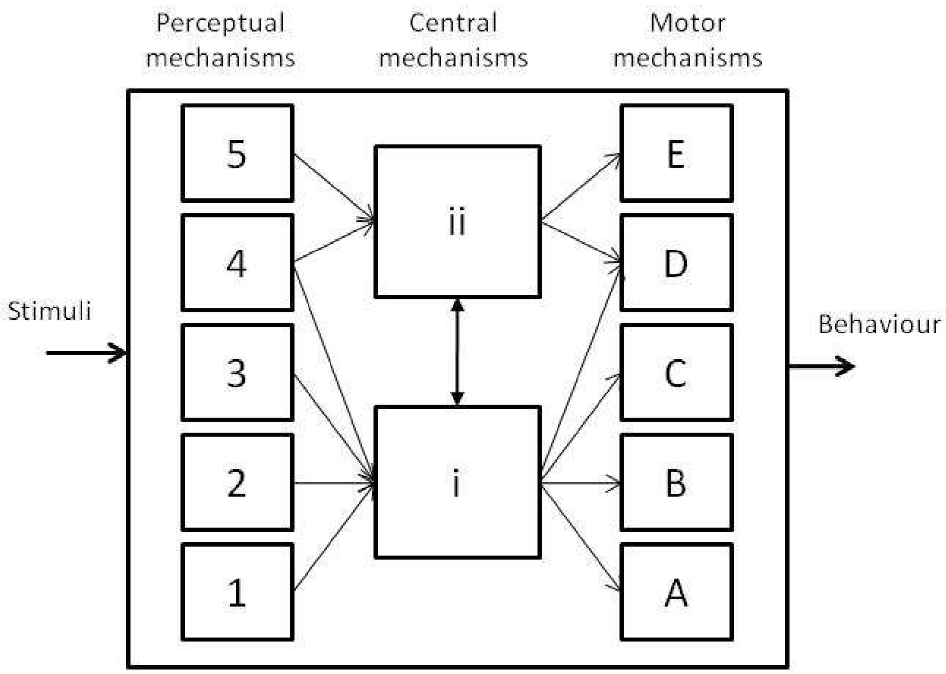


Figure 8. Conception of a behaviour system. Perceptual mechanisms (PM) 1-4 receive stimuli from the external world. Central mechanism (CM) i processes the output of the PM 1-4 and activates the motor mechanisms (MM) A-D. This forms a behaviour system. A second behaviour system is formed by [PM4-5, CM ii and MM D-E]. CM i and ii could also interact. The output of all MM results in behaviour. (Adapted from Hogan 2009, p. 37).

Activation of a behaviour system is influenced by stimuli, also described as motivational factors (Hogan, 2005). Motivation is described by Hogan as another term for Tinbergen's causal question and is understood as a combination of internal and external causal factors. Internal factors are situated in the body, while external factors come from outside the body. For example, a hungry animal is seeking food. Being hungry is caused by internal factors produced by the metabolism of the organism and seeking is directed by the environmental circumstances (external factors).

In fact, the arrows in figure 8 could be considered as the internal causal relations and these underline the third statement of Lorenz that behaviour is controlled by internal causal factors more than most scientists believed at that time (Tinbergen, 1963).

Behaviour patterns and systems develop in a dynamic process. Development is defined as the change in behaviour including the underlying mechanism in an individual from conception until death (Bolhuis, 2005) and is influenced by causal factors (Hogan, 2005). Therefore, within the question of the development of behaviour, the nature/nurture controversy has been debated: what is innate behaviour and which behaviour is acquired? The concept INNATE is confusing, because it has different meanings, e.g. 'present at birth', 'a behavioural difference caused by a genetic difference', or 'not learned'. In common usage, 'innate' means erroneously that behaviour is 'genetically determined' 'It is in our genes': as a matter of invariability. The discovering of a new gene for a distinct human characteristic or behaviour, such as aggression or alcoholism (Wang, et al., 2004), is reported frequently. However, while scientists report with the usual prudence, the reporting of these new genes in the media is somewhat simplified and therefore misleading (Bateson, 2001). Genes are often considered as more important phenomena than environmental variables for explaining mental development. Barendrecht (2004) called this the 'gene-doctrine'. Of course, the genetic component of many human characteristics and behaviour appears to be considerable (Van Aken, 2002), and because of the interaction between genes and the environment, behavioural genetics has resulted in a serious decrease of research on environmental influences on behaviour. However, nowadays,

> "…it is clear then, that because of the immensely complex system in which they [genes, JvM] are embedded, no simple correspondence is found between individual genes and particular behavior patterns or psychological characteristics. Genes store information coding for the amino acid sequences or proteins. That is all." (Bateson, 2001, p. 566).

Nothing happens in isolation and each behaviour pattern is affected by many different genes, while each gene influences many different behaviour patterns. Some genes are only expressed in special environmental circumstances. Therefore, the stimulus-response is not a single cause reaction, but is elaborated in networks (Bateson, 2001).

Moreover, research shows how subtle environmental factors cause variation between and within sexes. Crews & Groothuis (2009) illustrate this with the example of the influence of the incubation temperature on the development of the brain and social behaviour of the leopard gecko, a species where the sex determination is determined by temperature.

Consequently, the enormous progress of research in behavioural development has made the nurture/nature debate obsolete. Research in the area of behavioural development deals now with physiological processes and gene expression (Crews & Groothuis, 2009) and the assumption that every event has a single cause is slowly being replaced by an understanding of coordinated processes (Bateson, 2001; 2004).

However, behaviour is not only a coordinated process of causation; it is also a developmental process of acquiring behaviour. Development is induced by the mechanism by which individuals interact with and are changed by their environment (Kirkpatrick & Hall, 2005). This mechanism is called learning, which is defined by the Penguin Dictionary of Biology as the

> "acquisition by individual animal of behavior patterns, not just as an expression of a maturation process but as a direct response to changes experienced in its environment" (Thain & Hickman, 2000, p. 367).

This description emphasises the interaction between structures and the internal and external stimuli (see figure 8), which is not, as is often said, between heredity and environment. It is between organism and environment! Moreover, the organism is different at each state of its development (Lehrman, 1953). Nowadays, Lehrman's view is adopted by most students of behaviour (Hogan & Bolhuis, 2009b), and it is clear that the development of behaviour is seen as a complex and dynamic process (Bolhuis, 2005).

Organisms process their experiences in many ways. For example, imprinting is a learning process, where the dynamic character of development is notable. Imprinting is contemporarily defined as the learning process through which the social preferences of young animals become restricted to a particular stimulus or class of stimuli (Bolhuis, 2005). Imprinting occurs during sensitive periods, which means that the behaviour of an animal can be influenced by experiences in a particular phase of their development. These sensitive periods are probably caused by physiological clock mechanisms, related to the animal’s physical development, such as the growth of a neural network or increasing motor ability (Hogan & Bolhuis, 2009b). The end of a sensitive period can be induced by their development: once imprinted, the sensitive period ends. In addition to imprinting, other types of learning processes can be distinguished, which are summarized in table 2.

Furthermore, attention must be paid to the relation of learning processes with memory and cognition (Emery & Clayton, 2005). Animal cognition is the study of the processes resulting in adaptive or flexible behaviour in animal species (Andrews, 2008). Emery & Clayton (2005) characterized it as the study of the mental lives of animals, dealing with learning, memory and thought. In fact, learning is internal information processing by the individual (Levitis, Lidicker, & Freund, 2009) and cognition is the structure by which humans and animals acquire, process, store and act on information from the environment. However, the study of animal cognition is not free from pitfalls. Emery & Clayton (2005) associate the study of animal cognition with four pitfalls: anthropomorphism, anthropocentrism, the use of anecdotes as evidence, and unnecessarily complicated explanations of why an animal behaves in a certain way.

Table 2. Overview of learning processes, adapted from Kirkpatrick & Hall (2005), Emery & Clayton (2005) and Bolhuis (2005).

Learning process	Description
Imprinting	The learning process through which the social preferences of young animals become restricted to a particular stimulus or class of stimuli.
Habituation	The waning of a response with repeated presentation of its eliciting stimulus.
Imitation	A form of learning where the observer copies the actions of the demonstrator to achieve the desired goal. Social learning is the ability to learn from other individuals in the social group. It may be easier, safer, and quicker to profit directly from the experiences of other animals.
Conditioning	A process of behaviour modification by which a subject comes to associate a desired behaviour with a previously unrelated stimulus. Conditioning is simply stated as a stimulus-response association or associative learning: learning depends on the formation of associations.
Insight	The mechanism by which a novel problem encountered for the first time is solved immediately without recourse to the trial-and-error[7] learning method. Insight is a form of reasoning, maybe appearing by generalizing former experiences to principles or with the ability of animals to form mental representations of objects.

There is nearly no discussion about characterizing three of them as a pitfall, but while many (biology) behaviour researchers (and also biology teachers (Zohar & Ginossar, 1998)) consider anthropomorphic explanations of behaviour illegitimate, the scientific discourse about the usefulness of anthropomorphism is alive (Wynne, 2007a; 2007b; Daston & Mitman, 2005; Kennedy, 1992). Anthropomorphism is the attribution of human motivation, characteristics, or behaviour to nonhumans. The complexity of behaviour should imply conscious beliefs and desires, as some researchers argue (Wynne, 2007a). The statement that the presence of consciousness of animals cannot be excluded at all is based upon our own mental experiences of feelings, motivations and thoughts. Because of our awareness of these things in ourselves we take it for granted that animals feel and think too. The question “can animals think?” is therefore particularly posed in the field of comparative cognition and behaviour studies, dealing with the cognition and consciousness of animals (Griffin & Gayle, 2004). Another thought is that useful hypotheses for scientific study could be produced when projecting oneself into the situation of a member of another species (Wynne, 2007a). This form of anthropomorphic thinking as a tool for developing hypotheses is known as ‘critical anthropomorphism’, in contrast to ‘naive anthropomorphism’, a form of ‘folk psychology’. Examples of the use of critical anthropomorphism are found in the work of Brosnan & De Waal (2003) and Weir & Kacelnik (2006). Below we present an example of a text of De Waal, primatologist at Emory University, where he compares the emotion of laughing humans with animal behaviour.

[7] Trial and error is a method of reaching a correct solution or satisfactory result by trying out various means or theories until error is sufficiently reduced or eliminated (The American Heritage Dictionary of the Englisch Language, n.d.). It is questionable if trial-and-error is a biological learning process or a psychological method for problem solving where the learning processes as insight or conditioning (by reinforcement) play a role (Hull & Spence, 1938; Campbell, 1956). Since trial and error is not recognized as a biological learning process in Bolhuis & Giraldeau (2005) and Campbell & Reece (2005), it is not included.

"The infectiousness of laughter even works across species. Below my office window at the Yerkes Primate Center, I often hear my chimps laugh during rough-and-tumble games, and I cannot suppress a chuckle myself. It's such a happy sound. Tickling and wrestling are the typical laugh triggers for apes, and probably the original ones for humans. The fact that tickling oneself is notoriously ineffective attests to its social significance. And when young apes put on their play face, their friends join in with the same expression as rapidly and easily as humans do with laughter."[8]

Kennedy (1992) argues that anthropomorphisms are still alive. However, it becomes more implicit. He calls this neoanthropomorphism or unwitting anthropomorphism and he argues that anthropomorphic thinking about animal behaviour is built into us. However, the legitimate use of critical anthropomorphism in these articles is criticized by Wynne (2007b). The main contra-argument of the usefulness of anthropomorphism is that it is not a route for objective understanding, because humans can never understand the understanding of other species.

Function & evolution of behaviour

The concept FUNCTION has several notions in biology, so we need to define it for behavioural biology. Wouters (2003) distinguishes the concept FUNCTION in four manners: as an activity, as a biological (causal) role, as the survival value (biological advantage) and as a selected effect, as explained in table 3.

Table 3. Description of the four notions of the concept FUNCTION. Adapted from Wouters (2003, p. 635).

Function as	Description
1. Activity	What an organism (part or whole) does or is capable of doing. What is it doing?
2. Biological role	The way in which an item or activity contributes to a complex activity or capacity of an organism. How is it used?
3. Biological advantage	The advantages to an organism of a certain item or behaviour being present or having a certain character. How is it useful?
4. Selected effect	The effects for which a certain trait was selected in the past which explain its current present in the population. Why was it selected in the past?

The four notions of the concept FUNCTION can be positioned comprehensively (Boerwinkel, 2003), and are distinguished, because each different kind of function has a different explanatory role. However, each explanation level depends on the previous level.

Biologists still make the distinction between proximate and ultimate causes, where proximate causes focus on the environmental stimuli that trigger behaviour, and the ultimate causes address the evolutionary significance of behaviour (Campbell & Reece, 2005). However, the terminology of ultimate causes is misleading: ultimate causes are no causes at all; they do not bring about the response (Wouters, 2003; Bolhuis, 2009). FUNCTION described as activity and as a biological role could be seen as causal explanations, while the biological advantage and selected effect are functional explanations (Medicus, 2005).

[8] http://discovermagazine.com/2009/oct/19-monkey-see-do-connect/ (Retrieved November 2009)

In behavioural ecology, FUNCTION is seen as the biological advantage - the survival value, or as a selected effect or advantage (Cuthill, 2009). In the first case, FUNCTION is defined as the means by which behaviour increases fitness and it is synonymous with the current survival value. In the second case, the function of behaviour is the selective advantage that led to its current prevalence, so it has a historical character.

As we described before, Tinbergen (1963) distinguished the question of the function from the evolution of behaviour. In both questions behaviour is considered as aimed for survival, and survival strategies are important, such as impressive behaviour, territorial behaviour, social, and reproductive behaviour. In much research on animal behaviour, evolution refers both to the process of selection that gives rise to the evolution of adaptations, and the historical pattern by which biological diversity emerges (Ryan, 2005). Consequently, to avoid confusion, and following Tinbergen, a clear distinction between the function and the evolution of behaviour must be made. When speaking about the function of behaviour, we mean the third conception FUNCTION: function as a biological advantage (table 3). When speaking about the evolution of behaviour, the fourth connotation is intended: function as a selected effect.

Function, seen as a biological advantage, implies the question of why a specific behaviour pattern is useful. From Darwin's theory of natural selection, natural selection is seen as the process that leads to adaptations. Adaptations are defined as characteristics that exist because of the action of natural selection because they accomplish a function that contributes to an individual's fitness. Consequently, adaptations have a survival value (Giraldeau, 2005).

How can the change of a trait increase the fitness of an organism? FITNESS is expressed in the offspring of an organism in a particular environment. Therefore, the study of the function of behaviour embraces questions about sexual selection, and questions about optimality, for example in developing a foraging theory. Even questions about the defence of organisms are part of the research of the function of behaviour.

Within the question of the function of behaviour, COMMUNICATION is an important concept, because most of the time, it is a part of the behavioural repertoire of animals and it mediates fundamental aspects of their lives, e.g. reproduction and survival (McGregor, 2005). Furthermore, McGregor notes that

> "…communication is probably the area of behavior that best illustrates how answers to all four questions come together to provide more complete explanations." (McGregor, 2005, p. 227).

An example is research in neurobiological aspects of birdsong that includes both functional and mechanistic questions.

Communication also connects with other scientific disciplines. For example, psychology explains how communication is perceived and physiology, physics and chemistry help explain how communication is achieved.

The outcome of the study of the evolution of behaviour is a reconstruction. Such a reconstruction is to some extend a questionable enterprise, both because of the lack of fossil behaviour and because behaviour is the outcome of internal and external interactions. Tinbergen argues that the evolutionary study of behaviour has two major aims:

> "The elucidation of the course evolution must be assumed to have taken, and the unravelling of its dynamics." (Tinbergen, 1963, p. 428).

A way to explore the evolution of behaviour is through comparing the behaviour of groups of closely related species. In contemporary research, phylogenetic relations are used, because it gives less error than arguments based on strong logical inference (Ryan, 2005).

Darwin (1859) claimed that psychology would develop an evolutionary basis, which implies that a psychological continuum can be found between men and other organisms. Darwin published the well-known comparison of facial expressions between men and animals (Darwin, 1872). Contemporary research on human nature by the primatologist De Waal is also an example of this view (De Waal, 2005), although the idea of a psychological continuum was already criticized in the sixties by Hodos & Campbell (1969)[9].

Another topic of behavioural research is the evolution of social systems. Some animals form groups, which have a social structure and patterns of interaction and in many societies only one or a few of the group reproduce. The modelling of the reproductive differences among species may lead to a general theory of social evolution (Pusey, 2005). This realm includes issues of aggression, conflict resolution, cooperation and altruism. Studies of the evolution of social systems are linked with disciplines such as population biology, evolutionary psychology, and even economics, and are important for animal welfare and conservation biology.

Behaviour evolves under the influence of selection pressure. This selection pressure can be quite different in closely related species, while in distant species similar selection pressures may occur (Bolhuis, 2009). Furthermore, since mechanisms of behaviour can bias the direction of evolution, knowledge of causation of behaviour is necessary to explain the direction of evolution. A deep understanding of behaviour requires that all four questions of Tinbergen are involved (Ryan, 2005).

Animal behaviour and human society

The societal relevance of behavioural biology appears from its contribution to animal welfare, the conservation of species and the understanding of human nature (Bolhuis & Giraldeau, 2005).

The young field of applied animal behaviour science researches animal welfare issues, which arise in the management of wild, farmed, companion and laboratory animals (Fraser & Weary, 2005). Starting points for research are practical problems with animal housing, the interpretation and prevention of abnormal behaviour, and the affective states of emotions and feelings (fear, pain, distress). The affective state of an animal is a more controversial issue, because if refers to the psychological well-being of an animal. Do animals have psychological needs (Hogan, 2009)?

Although there is no universally accepted definition of welfare, it is generally agreed that physical and psychological (or mental) well-being are components of welfare. Animal welfare is the physical and psychological state of an animal as regards its attempt to cope with its environment (Broom, 1993).

[9] They argued that comparative psychologists had failed to distinguish between data from living representations of a common evolutionary lineage and data from animals that represent divergent lineages, which had consequences for the development of generalizations with any predictive value.

The World Animal Net, the world's largest network of animal protection societies with consultative status at the UN, in agreement with the World Society for the Protection of Animals, adds a third component: the state of naturalness. The state of naturalness refers to the ability of the animal to fulfil its natural needs and desires. The frustration of these natural needs and desires harms its welfare (World Animal Net, 2009). This concept implies that their welfare will suffer if animals are unable to express a normal range of behaviour patterns (Hogan, 2009). These three dimensions of welfare are also mirrored in the 'Five Freedoms', which were developed by the UK's Farm Animal Welfare Council and are used in many countries as a useful measure to assess animal welfare (EU, 1998). The Five Freedoms are a useful tool to identify situations that compromise good animal welfare – that is, any situation that causes fear, pain, discomfort, injury, disease, or behavioural distress. The Five Freedoms are:

- Freedom from hunger and thirst
- Freedom from discomfort
- Freedom from pain, injury and disease
- Freedom from fear and distress
- Freedom to express normal behaviour

Just as other research disciplines of behaviour, applied animal behaviour research stretches beyond the boundaries of animal behaviour research, combining behavioural observations with research to stress physiology and environmental design. Studies of causation are in particular numerous in the field of applied ethology and seek answers to practical problems that confront farmers or people who keep animals as pets. An example is feather picking of poultry, which decreases egg production. Research shows that feather picking is not caused by any single factor and there are indications that stress mediates the expression of feather picking (Hogan, 2009).

While animal welfare is about individual organisms, concerns about extinction and habitat loss of species, mostly caused by the disturbance of the environment by humans, are researched in the field of animal behaviour and conservation biology (Caro & Eadie, 2005). Conservation biology is concerned with the response of populations to environmental factors. There are two threads in conservation biology. First, the conservation of small populations, e.g. in a zoo, and second, the conservation of declining populations, which contributes to the conserving of endangered species in the wild (Caughley, 1994). The contribution of behavioural research to conservation biology is still limited (Suthterland, 1998) but its relevance is growing. For example, knowledge about behavioural research methods and ontogeny can provide practical tools to aid monitoring programs, or it can predict the effects of human disturbance on the size of a population (Caro & Eadie, 2005).

Finally, the understanding of human nature is a broad and interdisciplinary field of interest. Although human behaviour seems to have unique traits, such as language and culture, and its own science (e.g. social science and anthropology), the study of animal behaviour could shed light on the behaviour of humans (Daly & Wilson, 2005). Many other disciplines of biology rely on the continuity of anatomy, physiology and brain between humans and nonhumans, using animal models, in particular when research on human beings is too risky or unethical. In behavioural biology, animal models are also used to research human behaviour and cognition, for example the use of rats to explore memory tasks or the study of aggression. Parallel developmental processes in humans and animals have been discovered (Hogan & Bolhuis, 2009b), while homologous structures in the brain may be studied with the use of MRI techniques.

4.3 Implications for education

In the previous section, we presented an overview of the current development and concepts of behavioural biology. In this section, we will discuss the topics and concepts of behavioural biology to which secondary education should pay attention. Because it is impossible to cover all behavioural biology, we will take the main points and make a selection of concepts.

Considering the developments in the field of the behavioural sciences as reviewed in the previous section, we draw three conclusions. First, behavioural biology is a *dynamic* research field with many cross-links to other research disciplines that consider behaviour. Developments in this research field are abundant because of the use of new research techniques, such as fMRI-scans of the brain. Because of the many cross links and the start of novel research disciplines, behavioural biology may be considered an important discipline. Therefore, teaching a broad view of behavioural biology instead of ethology, as pleaded by Bolhuis (2002), should be part of secondary biology education.

The second conclusion is that behaviour should be considered as emergent property of a *dynamic* and *complex* system. Although there is no unambiguous definition, a complex system may be defined in general as a system in which many independent components interact with each other in multiple (sometimes infinite) ways, difficult to predict and resulting in emergent properties not reducible to their elements (Brownlee, 2007; Heylighen, 2008; Agar, 1999). A complex system is also adaptive (i.e., they always adapt in a way that benefits them), and the basic concept of complexity is that all components tend to organize themselves into patterns. Ant colonies and immune systems are examples of complex systems.

Behaviour is multicausal, and organisms behave in interaction with environmental factors at multiple levels of biological organization. As shown from the definition of behaviour (Levitis, Lidicker, & Freund, 2009), there is no non-behaviour and behaviour is reserved to whole organisms and populations, although the causes of behaviour operate at multiple levels of biological organization. Behaviour cannot be explained by analysing its components or from only one perspective.

Teaching a broad view of behavioural biology while accounting for the complexity of behaviour needs to consider a systems approach. The theoretical biologist Ludwig von Bertalanffy (1968) articulated an organismic approach to the study of life with his General Systems Theory (GST), and based on his work other systems theories are developed. A systems theoretical approach requires a systems thinking competence that could be described as being able to study biological phenomena from a systems perspective (Verhoeff, 2003; Boersma, Waarlo, & Klaassen, 2011). As Knippels (2002), Verhoeff (2003) and Westra (2008) argued, the systems thinking competence may help students to understand the coherence between concepts.

The third conclusion is that concepts of behavioural biology may be *structured* according to the four questions of Tinbergen. As we described in the previous section, behaviour should be explained from four perspectives and seen as a dynamic complex system. Therefore, a well-defined set of concepts is necessary. Table 4 indicates the concepts of behavioural biology, selected from section 4.2. From the index of the book of Bolhuis & Giraldeau, all concepts that are quoted minimal four times were classified by the four questions of Tinbergen. In keeping with the goals of behavioural biology the societal relevance of behavioural biology could be defined as being concerned with animal welfare, conservation of species and the understanding of the human nature (Bolhuis & Giraldeau, 2005).

Table 4. Concepts of behavioural biology, categorized by the four questions of Tinbergen, as described from section 4.2 and concepts related to the (social) relevance of behaviour.

	Concepts
Causation	Internal and external stimuli, Behaviour system, Behaviour pattern, Motivational factors, Motivation, Biological rhythms, Proximate causes.
Development	Learning, Habituation, Imprinting, Imitation, Conditioning, Insight, Innate behaviour, Acquired behaviour, Heredity, Sensitive period, Cognition, Anthropomorphism.
Function	Survival value, Feeding, Reproduction, Defence, Communication, Group behaviour, Ultimate causes, Impress behaviour, Territory behaviour, Social and reproductive behaviour
Evolution	Fitness, Natural selection, Permanent adaptation, Evolution of social systems.
Relevance	Welfare, Natural behaviour, Stress, Conservation of species, Extinction, Habitat loss, Understanding human nature.

4.4 Design criteria for a learning and teaching strategy

The implications for education as described in the precious section result in a set of design criteria for an LT-strategy for behavioural biology.

1. An LT-strategy should be based on 21st century behavioural biology, which means at least that links must be elaborated with other biological disciplines such as physiology, genetics and psychology.

2. Students should be aware that behaviour emerges in a dynamic and complex system, which results from multiple causes and develops through the interaction of the organism with its environment. Therefore, an LT-strategy should emphasise systems thinking to achieve awareness of behaviour and coherence between concepts.

3. The behavioural biology concepts in an LT-strategy should be structured according to the perspectives of causation, development, function and evolution of behaviour.

4. An LT-strategy should pay attention to the social relevance of behavioural biology in order to develop students' understanding of its relevance.

5 Defining educational practice in behavioural biology

5.1 Introduction

In the previous chapter we described an overview of 21st century behavioural biology and formulated design criteria for an LT-strategy for behavioural biology. If behaviour is as important as it seems to be the question arises how the topic behaviour is taught and learnt in biology education in the Netherlands today and how it should be taught in the future.

In Dutch secondary education, the final examination is divided into a school examination and a central examination. Since 1994 in pre-university education (vwo) and 1995 in upper general secondary education (havo) ethology is part of the Dutch central biology examination. Previously, any biology teacher had a large degree of freedom in teaching ethology, and assessed the topic in a school examination. From discussions with biology teachers, Van de Veen-Unema (1980) concluded that some of them did not know what to do with the topic. However, the need for teachers to increase their efforts in teaching ethology after its introduction in the central examinations is still not clear. An analysis of eight central exams in havo and vwo (2001-2004, two series a year) shows that students hardly need knowledge of ethology, because the topic is particularly used to assess (research) skills (Van Moolenbroek, Boersma, & Waarlo, 2005). A maximum of five points out an average of eighty points were addressed to ethology, and half of those questions were attributed to the question of function, while the other half covered the questions of ontogeny and causation. Consequently, it can be concluded that there is still no tradition in teaching ethology in the Netherlands (Dijkstra & Jansen, 1993). Therefore, in the exploration phase we investigated the question of the current educational practice more in detail. We analysed current Dutch biology textbooks and students‘ prior knowledge about behaviour. Section 5.2 presents the results of that analysis. In section 5.3 we discuss the conclusions and implications of the previous section for the innovation of behavioural biology teaching in secondary biology education. This discussion results in a set of learning objectives for behavioural biology in secondary education (section 5.4).

5.2 Exploring current educational practice

In line with the design criteria described in section 4.4 three questions could be asked.

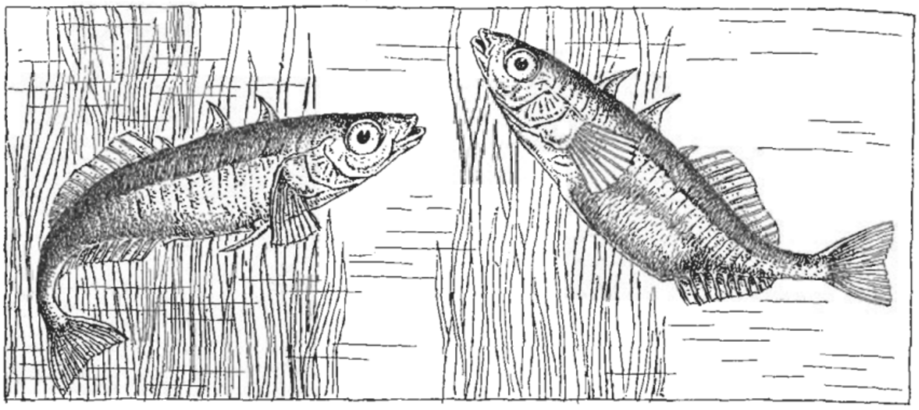
1. To what extent is a broad or narrow view of behavioural biology elaborated in current educational practice? As we posed in the first design criterion, the teaching of behavioural biology should be based on 21st century behavioural biology, and linked to other disciplines as physiology, genetics, and psychology.

2. Does the current educational practice emphasise behaviour as a dynamic and complex system?

3. In what manner are the four questions of Tinbergen addressed in the chapter about behaviour in current Dutch biology textbooks and in the thoughts of students?

5.2.1 *Behaviour in current Dutch biology textbooks for secondary education*

For many American psychologists and biologists the publishing of the article "The Curious Behavior of the Stickleback" (Tinbergen, 1952) in *Scientific American* was a first exposure to the concepts of ethology (Dewey, 2007). This article became influential and the research on behaviour of the stickleback stood as a model in biology textbooks. Figure 9 shows a picture of the 'zigzag' behaviour of the stickleback as described by Tinbergen (1952).



IN FIRST STAGE of courtship the male stickleback (*left*) zigzags toward the female (*right*). The female then swims toward him with her head up. The abdomen of the female bulges with from 50 to 100 eggs.

Figure 9. Picture of zigzag behaviour from the original article of Tinbergen (1952).

The same kinds of pictures of the stickleback are included in recent Dutch biology textbooks. Figure 10 shows pictures of courtship behaviour of sticklebacks in a popular scientific textbook from 1978 ('t Hart, 1978), and a recent textbook for secondary biology education at pre-university level (Bijsterbosch, Maier, & Van Wijk, 2004). The same pictures can be found in several other biology textbooks, including the frequently used textbook 'Biology' (Campbell & Reece, 2005).
From the work of the first ethologists, research on bees and seagulls (Tinbergen), geese (Lorenz), the Skinner box, and the Pavlov experiment[10] are noted in recent biology textbooks. Of course, nothing is wrong with these examples, but they are all examples based on work of the first ethologists, and the question is if these textbooks represent 21st century behavioural biology.

What should be taught in upper secondary biology education is indicated in the examination programs (OCW, 2007; Legierse, 2007) and is specified in syllabi (CVE, 2010). The current attainment targets about behaviour in Dutch upper secondary education cover three of the questions of Tinbergen, causation, function and ontogeny. They do not cover the evolution of behaviour and notions about human behaviour are limited. More in detail, the attainment targets prescribe students' understanding of the behaviour of the stickleback.
Since Dutch teaching practice is more influenced by the textbook than by the syllabi we also analysed four commonly used Dutch biology textbooks at vwo and havo level and 'Biology' (Campbell, 1996; Campbell & Reece, 2005), which is seen as an adequate base for the study of Biology and is used in the training of biology teachers (Van Moolenbroek, Boersma, & Waarlo, 2005).

[10] The Pavlov reaction is even part of the Dutch 'Bètacanon,' a list of 50 topics of science which every Dutchman should know. www.betacanon.nl. (Retrieved February 2012)

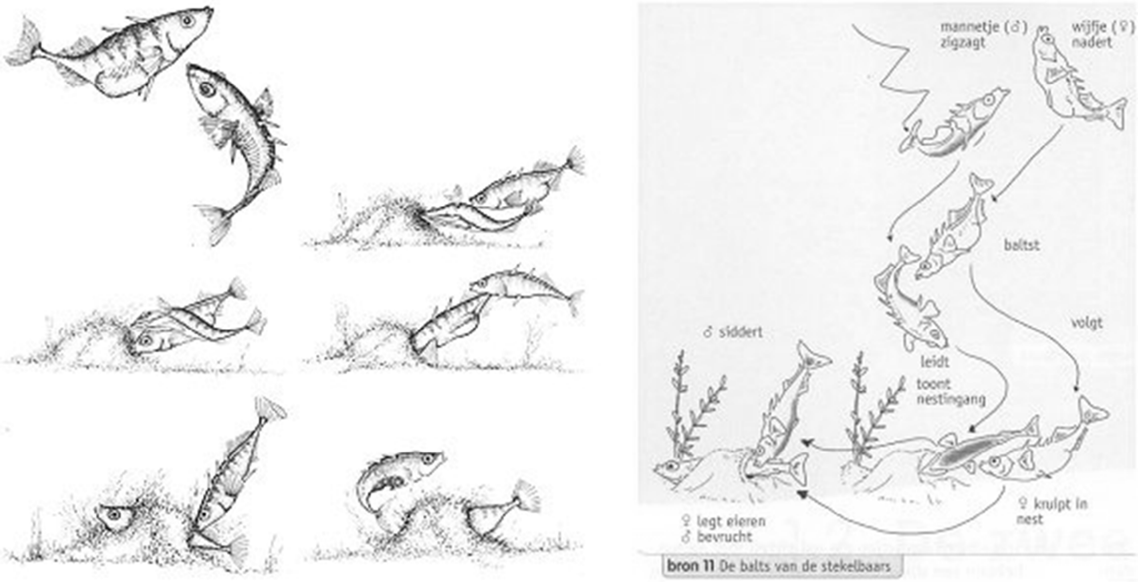


Figure 10. Pictures of the courtship behaviour of the three-spined stickleback in the left pane from ‘t Hart (1978) and in the right pane from a textbook for secondary biology education at pre-university level (Bijsterbosch, Maier, & Van Wijk, 2004, p. 19).

How are Tinbergen's four questions represented in Dutch biology textbooks?

To determine how the four questions of Tinbergen are answered in Dutch biology textbooks, we collected a list of all concepts from the chapter about behaviour in the biology textbooks. In total 59 concepts, linked to behaviour, were classified in the four categories: causation, ontogeny, function and evolution (figure 11).

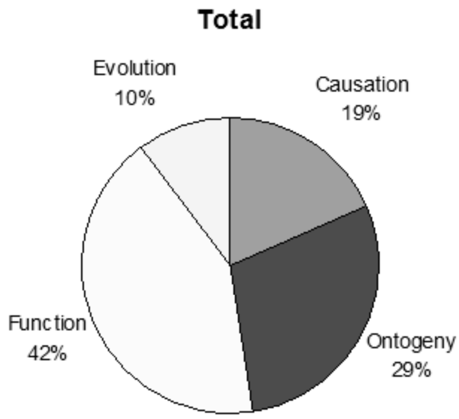


Figure 11. Relative distribution of behavioural biology concepts across four categories representing the four questions of Tinbergen.

After classification, concepts in each textbook were scored to gain more insight in the distribution of the four questions per method. Figure 12 gives this distribution of concepts in percentages for four of the most frequently used biology textbooks. It is clear that the functional question is most frequently represented, while causation and ontogeny each take approximately 25%. This corresponds with the emphasis that was laid on the functional question during the seventies of the last century, as described in chapter 4.

In Campbell's Biology (Campbell, 1996) the chapter Behaviour is the last one of the book and in 8 of the 14 paragraphs evolution of behaviour takes an important place. The classification of the chapter in 'Campbell' is based on several research domains from ethology, such as behavioural ecology, cognitive ethology and socio-biology, completely in line with the prevailing conceptions of the seventies in the last century. In a latter edition (Campbell & Reece, 2005) the chapter is placed at the beginning of the sector about ecology, the study of interactions between organisms and the environment, but the big picture is the same as described previously.

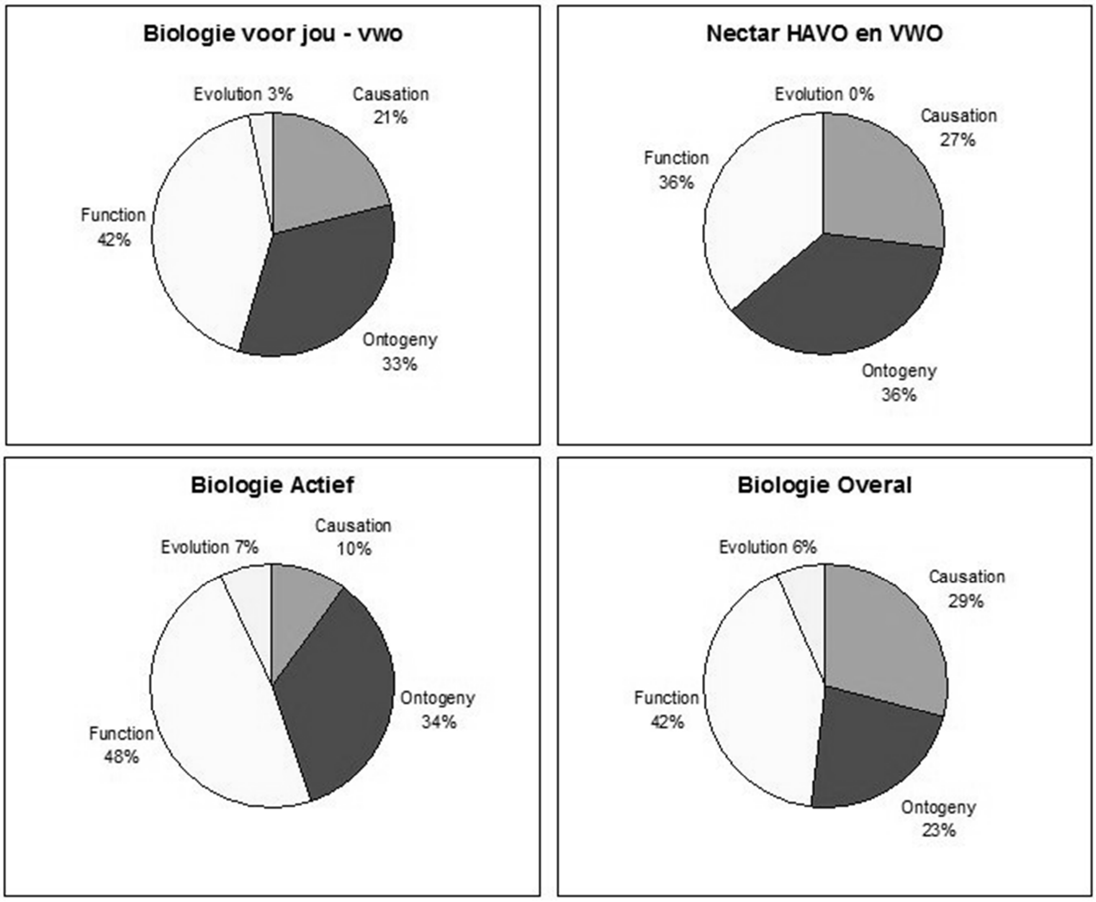


Figure 12. Classification of concepts of the behaviour chapter in four Dutch biology textbooks for secondary education. (vwo = pre-university level; havo = upper general secondary education)

Is behaviour viewed in a broad or a narrow view?

The question if a broad or narrow view on behavioural biology is presented in textbooks is answered by checking statements about the relation between ethology and psychology and genetics, and about societal consequences of animal behaviour research or animal welfare. These statements showing the actual developments of behavioural biology are presented in the textbooks only to a limited extent. Heredity of behaviour is generally addressed in the discussion about nature/nurture, while coherence

between genetics and behaviour and between hormones and behaviour is not elaborated. The chapters about behaviour do not refer to other disciplines of biology, such as physiology.
The placement of the behaviour chapter in biology teaching textbooks is another indication for a broad or narrow view. Sometimes, the behaviour chapter is situated at the beginning of a textbook, but generally, it is placed at the end. Since behaviour is an isolated topic in textbooks, it indicates a narrow view.

The complex nature of behaviour in biology textbooks

Do current biology textbooks emphasise behaviour as a dynamic and complex system? As we have discussed in section 4.3, the dynamic and complex nature of behaviour should be presented in biology textbooks in an adequate manner, following Tinbergen's four questions and exploring different levels of biological organization. However, because of the narrow view, different levels of biological organization are not necessarily explored. Therefore, it can be concluded that behaviour is not presented in the textbooks as the result of a complex system. The introduction of the chapter Behaviour from a frequently used biology textbook, 'Biologie voor jou' (Biology for you) is an illustration of this conclusion:

> Introduction
>
> Your parents or teachers have probably made comments on your behaviour. For example: "Be quiet". They wanted your mouth or body would show less movement. All your activities seen together are your behaviour. Even animals exhibit behaviour.
>
> The issue that is first addressed is how behaviour is studied. Then we discuss how behaviour is caused and what factors determine behaviour. Also, various forms of behaviour are discussed. Finally, we will discuss similarities and differences between the behaviour of animals and humans. (Smits & Waas, 1998)

In this textbook 'studying behaviour' focuses on behaviour systems, fixed action patterns, an ethogram, and protocol. In contrast with the definition of behaviour, behaviour is only seen in this textbook as actions and not as inactions. 'Forms of behaviour' stands for the function of behaviour, while behaviour is 'determined' by heredity and learning processes. Speaking about human behaviour, the textbook states that learning processes for humans are more important than they are for animals. In short, the afore-mentioned quotation is exemplary for Dutch biology textbooks and therefore it could be concluded that systems thinking, as a manner to understand the dynamic and complex nature of behaviour, would not be supported by Dutch biology textbooks. This is in line with findings of others who pose that system thinking is usually not taught in Dutch biology education (Boersma, 1997; Knippels, 2002; Verhoeff, 2003).

5.2.2 Students' ideas about behaviour

From our view on learning and teaching (see chapter 2) it is clear that pedagogy should use strategies that connect students' prior knowledge with relevant concepts in behavioural biology. Therefore, in the explorative phase of this study we also investigated the prior knowledge and ideas of students about behaviour of human beings and animals (Van Moolenbroek, Boersma, & Waarlo, 2007). This study is of critical importance, because no scientific educational research about this topic could be found. The aim of the research was to discover the following:

1. To what extent are the four questions of Tinbergen reflected in students' expressions?
2. How do students describe the behaviour of animals and humans?
3. How do students give meaning to observed behaviour?
4. How do students compare human behaviour with animal behaviour?
5. How do students think about the relevance of behavioural biology?

These research questions were answered by questioning students in open interviews. From three schools for secondary education 38 students aged 15-16 years, in the fourth class of pre-university level were questioned. Not all students had previously instruction about behaviour.

Topics of the interviews were the experiences of students with pets and the behaviour of some animals, as shown in some video fragments. A system of categories was developed from the interviews and all sentences were classified. Table 5 shows the relative distribution (%) of these categories.

Table 5. Relative distribution of 1057 sentences of students (n=38) about behaviour (From: Van Moolenbroek, Boersma, & Waarlo, 2007).

Category	Relative distribution (%)
1. Four questions	
Causation	15
Ontogeny	25
Function	14
Evolution	1
2. Description	
Affection	5
Observation	30
3. Give meaning to behaviour	2
4. Comparison human-animal	5
5. Importance of behavioural research	2
Others	1

After examining the qualitative data it was concluded that students explain behaviour from several causes, whereby the stimulus ‘fear' is most frequently mentioned. This probably could be explained by their experiences with the topic of the interview, pets. Pets are generally prey animals.

The students’ statements show both internal and external factors, but students are not aware that they infer a causal relationship or, for example, that internal factors are related to the physiology of an organism. Comparably, external factors were not related to ecology.

Only a few statements were found about the role of genes in the development of behaviour. Genetic determinism seems to play no role in the thoughts of students: some behaviour is in the genes, and some behaviour gets learnt, so in students' views there seems to be no controversy between nature and nurture. Furthermore, students see the difference between innate and learnt behaviour as a continuum.

However, the concept INSTINCT is indistinct. In his ‘Origin of species’, even Darwin (1859) did not make a bid to define the concept INSTINCT.

Students mention a few learning processes, whereby conditioning is understood as education. They consider imitation as a learning process, but the lack of further attention to leaning processes evokes the question if students see learning processes as a part of behaviour.

Students recognize ‘survival’ as the most important function of behaviour, but an evolutionary explanation of behaviour is not coming to their mind.

Students speak only affectionately about behaviour when they speak about their pets. Students use examples to clarify their statements and use anthropomorphic language in nearly the half of these statements. Anthropomorphic language is not only used when they speak about their experiences with pets, but also when they describe animal behaviour seen from a video. In short, students seem to attribute volition and feelings to animals.

Although students find it difficult to give meaning to observed behaviour, they think that this should be done by ‘looking and comparing’. ‘To look’ is then described as observing and describing behaviour, while students ‘compare’ by making parallels between animal behaviour and their own or by comparing behaviour in different circumstances. Students make a distinction between animal behaviour and human behaviour by noting differences in intelligence, volition, and conscience. Finally, students find the topic of behaviour very important, but attain no self-insight from it.

Dijkstra & Jansen (1993) pose that students like to focus on concrete human behaviour, but their knowledge is generally not ethological. On the base of our research we confirm this statement. Generalizing, we concluded that students only have *general notions of behaviour* and that they are *not curious* about behaviour. Curiosity evokes questions about the ‘why' of observed phenomena and is the same as independent thinking (Rondhuis, 2004). Questions disappear when curiosity disappears and curiosity disappears when uncommon phenomena are seen as common (Jansen & Jacobs-Scheper, 2002). The statement that behaviour is very common for students could answer the question why students did not wonder about behaviour. They were not aware that behaviour could be a biological phenomenon that can be investigated.

5.2.3 Conclusions and implications

We explored the current Dutch educational practice for behavioural biology by investigating the chapters about in the Dutch biology textbooks and the prior knowledge of students about behaviour. We address our findings to three questions, derived from the formulated design criteria for an adequate LT-strategy.

1. To what extent is a broad or narrow view of behavioural biology elaborated?
2. Is behaviour emphasised in current biology education as dynamic and complex?
3. In what manner are the four questions of Tinbergen addressed in the behaviour chapter of Dutch biology textbooks and in the thoughts of students?

Although the content of the chapter on behaviour in the textbooks is an adequate interpretation of the prescribed topics about behaviour, it is based on the state of the art in the ethology of 30 years ago and it shows a narrow view of behavioural biology. The Dutch examination programs are strongly based on the so-called Program Base of the Biological Council (KNAW, 1967; Boersma, et al., 2005), which means that the examination programs in secondary education have not been fundamentally changed recently. The textbooks do not emphasise the dynamic and complex character of behaviour and lack a reference to the four questions of Tinbergen. On the contrary, relevant concepts are spread over the whole chapter, so there is no coherence between concepts, while evolution of behaviour is generally neglected.

With these textbooks it is imaginable that current behavioural biology education does not lead to awareness of behaviour as dynamic and complex, but rather to some general notions of behaviour. The lack of structure by the four questions of Tinbergen and the lack of relevance between behavioural biology and other disciplines of biology is not adequate for students' understanding of behaviour.

Of course, in addition to biology textbooks and students thoughts the practice of the biology teacher is also important, but teacher's ideas or practices were not investigated. Furthermore, Boersma (1997) argues that the current teaching of biology is not very helpful to students, because it does not pay attention to systems thinking. If this conclusion is correct, it is not very likely that the teachers' practice could compensate the shortcomings of the biology textbooks. In general, with the available textbooks no 21st century behaviour can be taught. That implies that current education in behavioural biology should be innovated, leading to a greater awareness of behaviour.

5.3 Towards an innovation of secondary behavioural biology education

In chapter 4, we presented an overview of 21st century behavioural biology and its implications for biology education. Behaviour should be taught as a dynamic and complex phenomenon, the four questions of Tinbergen should be discussed, and behavioural biology should be defined as a dynamic research field with cross-links to other domains in biology. In the previous section 5.2, we described current behavioural biology in secondary education, resulting in the conclusion that the textbooks are not adequate for teaching 21st century behavioural biology and that students only have a general notion of behaviour. Taking these conclusions into account in this section the question will be answered which concepts are needed to adapt the current practice for behavioural biology education today. First, we argue for a selection of relevant behavioural biology concepts (subsection 5.3.1). In the subsequent subsections 5.3.2 to 5.3.4, a coherent web of concepts is built.

5.3.1 Selection of relevant behavioural biology concepts

To create a balanced curriculum and to avoid curricular overload, Van den Akker (2003) suggests first, to focus on core concepts and second, to create interaction between learning inside and outside the school. And in the third place, to increase students’ motivation to learn, one should move from traditional, teacher- and textbook-dominated instruction towards meaningful, activity-based, and autonomous learning approaches. Although the last two points seems to indicate for pedagogical criteria, they could also be explained as a need for choosing concepts or subjects that either are relevant for society or increase the interest of students. Therefore, a curriculum should have scientific and societal relevance and must be relevant for learners.

Since the same curricular problems of science education, overload, lack of coherence and lack of relevance are reported from other countries (e.g. Gilbert, 2006), we consulted three other educational sources concerning behavioural biology education, and investigated which concepts of table 4 are relevant from a societal and personal perspective. Subsequently, we paid attention to Project 2061 of the American Association for the Advancement of Science (AAAS), the National Science Education Standards (NSES) of the American National Academy of Sciences (NAS), and a German approach (Puhlfürst, 2005).

In 1989, the American Association for the Advancement of Science (AAAS) started Project 2061 to improve science education for all students (AAAS, 2009a). Project 2061 includes Benchmarks[11] for scientific literacy, which help educators to reconsider their curriculum (AAAS, 2009b). The Benchmarks present a basis for learning goals at four levels, from Kindergarten to Grade 12. Science in Project 2061 is considered from a human perspective, since terms and circumstances change during the human life span, and science and technology are in the centre of these changes. The Project 2061's Benchmarks for scientific literacy indicate the relevant ideas for science education. Therefore, it is interesting to see how the concept BEHAVIOUR is elaborated.

The concept BEHAVIOUR[12] is found in three chapters in the Benchmarks of Project 2061. The chapter *The Living Environment* deals with the interaction between behaviour and the environment. More about animal and human behaviour is included in the chapters *The Human Organism* and *The Human Society*. The chapter *The Human Organism* (Ch. 6) emphases that BEHAVIOUR is constituted by both inheritance and experience, with learning as an important distinction between humans and other species:

> "Human behavior results from the interaction of inheritance and learning. Besides being a basic function of most animals, learning defines the most prominent way in which human beings are different from other species." (Ch. 6, *Learning*).

Summarizing, this chapter of the Benchmarks emphasises the causes and development of behaviour[13]. Chapter 7, about *The Human Society*, focuses obviously on cultural influences on behaviour, including acting in a group and dealing with peer pressure.

> "Differences in the behavior of individuals arise from the interaction of heredity, culture, and experience—the effect of each depends on the other." (Ch. 7, *Cultural Effects on Behavior*).

Communication is seen from a sociological (Ch. 7, *Social Conflict*) and a technological view (Ch. 8: *The Designed World, Communication*).

Summarizing, we conclude that in the Benchmarks of Project 2061 emphasis is put particularly on the interaction of organisms with their environment.

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[11] http://www.project2061.org/publications/bsl/online/index.php (Retrieved October 2009)

[12] Searched with 'behavior' (Retrieved October 2009)

[13] However, the Benchmarks use the concept BEHAVIOUR in an inconsistent way by the use of terms as 'social behavior', 'genetically determined behavior' and 'instinctive behavior' or even 'free-market behavior'. Here, we only consider the behaviour of humans and animals.

Another source is the National Science Education Standards (NSES) of the American National Academy of Sciences (NAS). The NSES (NAS, 1996) are a set of guidelines for science education in primary and secondary schools in the United States, as established by the National Research Council in 1996. Guidelines are indicated for elementary, middle and secondary schools, and have influenced various learning standards.
What do they indicate about behaviour? First, at the level of the middle school:

> "Behavior is one kind of response an organism can make to an internal or environmental stimulus. A behavioral response requires coordination and communication at many levels, including cells, organ systems, and whole organisms. Behavioral response is a set of actions determined in part by heredity and in part from experience. (…) An organism's behavior evolves through adaptation to its environment. How a species moves, obtains food, reproduces, and responds to danger is based in the species' evolutionary history. (NAS, 1996, p. 157)

Three conclusions could be inferred from this text. First, behaviour is seen as a response: it is the outcome of internal and external stimuli, which means that an organism is always showing behaviour. Second, the description emphasises behaviour as a coordinated response at several levels of biological organization, which should be understood as an indication for a complex system. Third, FEEDING, REPRODUCING and DEFENDING as behavioural systems are mentioned as functions of behaviour.
For the next level of secondary school (9-12) the topic behaviour is included in the section *Life Science*. Within this topic, students have to acquire not only an understanding of the cell, heredity, and evolution, but also of the behaviour of organisms:

> "Multicellular animals have nervous systems that generate behavior. (…) Organisms have behavioral responses to internal changes and to external stimuli. (…) these responses either can be innate or learned. (…) Behavioral biology has implications for humans, as it provides links to psychology, sociology, and anthropology." (NAS, 1996, p. 187)

The statement that behaviour is 'generated' by the nervous system is rather incomplete, although it is followed by a statement about the senses. However, as we saw in section 4.2 (figure 8), the mechanism of behaviour consists of more than just nerves. As in the description at K5-8 level, the 'old idea' of the dichotomy of innate and learned behaviour is included. The text is not referrin to learning processes. Behavioural responses are caused by interaction between the organism and the environment, instead of partly by heredity and partly by the environment. At the K9-12 level the NSES takes in account the implications of behaviour for humans and ads cross links to other scientific disciplines.

Both the Benchmarks and the NSES support our view of current educational practice: reasoning from an unclear notion of (the definition of) behaviour and how the topic could be structured. Therefore, it is questionable if the aforementioned descriptions could contribute to a coherent curriculum, leading to a better understanding of behaviour. There is no consistent whole of concepts, even over different levels of education. It seems that behaviour erroneously is not seen as the outcome of a complex system.

Behavioural biology education has also been discussed in Germany (Puhlfürst, 2005). From 1996 on a research group develop a scheme for behavioural biology education, especially human behaviour. In this view, behavioural biology education should include the following themes:

A. History of ethology

B. New ways in behavioural biology: socio-biology, neuro-ethology, and behavioural ecology.

C. Systematic thought

D. Limits of behavioural sciences

E. Meaning of behavioural findings for humans

Concepts and topics are categorized in (1) goals of behaviour, (2) the ontogeny, (3) mechanisms and (4) function of behaviour (including evolutionary concepts). These categories are in accordance with the four questions of Tinbergen.

The foundation of theme E is interesting for our question about the social and personal relevance of behaviour. Not all animals live in their natural environment, e.g. farm and zoo animals. Their environmental limitations include that they should adapt. Humans have to take into account with the limits of adaptation by observing behavioural changes. Therefore, the meaning of behavioural findings for humans is raised from the welfare of animals.

In addition, according to the German approach human behavioural biology education should address

- the phylogenetic adaptation of humans to an environment of hunters and collectors;
- the limited adaptability of humans;
- the (social) stress because of the drifting apart of human nature and civilization;
- the multifunctionality of much behaviour;
- the elaboration of (human) behavioural biology into other sciences.

(Puhlfürst, 2005)

From this list can be noticed that the limits of the adaptability of humans and social stress are emphasised. It could be relevant for students to understand how their behaviour in stress situations is restricted. The German approach is considered as an effort to elaborate a systematic overview of behavioural biology in biology education. The four questions of Tinbergen, supplemented with the goals and methods of behavioural biology research, are used to structure the domain, while the human perspective is the starting point. However, the German approach seems to propose an innovation of the content, without recognising behaviour's dynamics and complexity. Furthermore, it is remarkable that in this German approach so many concepts (40) were selected.

It seems that the three approaches discussed here do not show new insights. The goals of behavioural biology education must express social and personal relevance for students. In addition, it seems unlikely that the approaches will be elaborated towards a coherent and relevant curriculum for behavioural biology in secondary education, in which behaviour is seen as the outcome of a dynamic and complex system.

Finally, we will answer the question which concepts of behavioural biology have to be taught as a minimum. In table 6 we present the concepts that are relevant in learning and teaching behavioural biology. With this selection of concepts a coherent understanding of the behavioural biology can be safeguarded. Basic concepts are defined as the minimally needed concepts to understand behavioural

biology. In table 4 (section 4.3) we indicated the concepts of behavioural biology, categorized by the four questions of Tinbergen, and concepts related to the social relevance of behaviour. From this overview, concepts can be categorized at a higher level of abstraction. For example, the concept HORMONE is brought under the concept INTERNAL STIMULUS. Consequently, observable behaviour in the category 'Function' is gathered together in three subcategories: FEEDING, REPRODUCTION and DEFENDING.
Subordinate concepts are defined here as (1) non-behavioural biology concepts (e.g. HEREDITY, WELFARE), that show in particular the societal and personal relevance and (2) the behavioural biology concepts that could be omitted to reduce curricular overload (e.g. COMMUNICATION, GROUP BEHAVIOUR).

Table 6. Basic and subordinate behavioural biology concepts, relevant in learning and teaching behavioural biology in secondary education.

	Causation	Development	Function	Evolution
Basic concepts	Internal and external stimuli	Learning Habituation Imprinting Imitation Conditioning	Survival Feeding Reproduction Defence	Fitness Natural selection Permanent adaptation
Subordinate concepts	Heredity Stress Human nature	Adaptation Heredity Human nature	Communication Group behaviour Welfare (incl. natural behaviour) Stress	Conservation of species

5.3.2 *Evoking coherence between concepts*

Selection and structuring of relevant concepts is a requirement for education, just as inducing coherent conceptualisation. Many students do not develop coherent biological knowledge (KNAW, 2003), because they do not understand that biological processes include different levels of biological organization.
In our view on learning and teaching, we emphasise conceptual development within social practices, wherein the meaning of a concept depends on the context in which the concept is used. In chapter 4 we argued for a dynamic and complex nature of behaviour and suggested that systems thinking could be supportive in acquiring this understanding, since systems thinking enables dealing with the multi-causality of behaviour. It seems to be important to show the interrelationships between relevant concepts of behavioural biology, and the coherence between different levels of biological organization (Boersma, Waarlo, & Klaassen, 2011).
Furthermore, Vosniadou & Ioannides (1998) argue that science learning is a gradual process during which students' conceptual structures based on their interpretations of everyday experiences are continuously enriched and restructured. Roseman, Stern & Koppal (2010) in presenting a method for analysing the coherence of high school biology textbooks, maintain that coherent textbooks should

a) present a set of age-appropriate scientific ideas and connections among them;

b) clarify the ideas and connections with effective representations;

c) illustrate the application of the ideas to objects, events, and processes in the real world;

d) avoid the use of unnecessary technical terms or details that are likely to distract students from the main story. (Roseman, Stern, & Koppal, 2010, p. 50)

According to Boersma et al. (2005) in the concept-context approach coherence should be distinguished at different levels, including coherence between concepts. Therefore, the question is how to construct with the concept shown in table 6 a coherent model of concepts for behavioural biology that can be learnt and taught gradually.

Summarizing, we suppose that conceptual coherence of behavioural biology emerges when students have the possibility to explore different levels of biological organisation, can relate behavioural biology concepts to their everyday experiences, and when they have the possibility to build up a concept web gradually. Therefore, in the next sections, we will describe the use of concept maps (5.3.3) as a tool for the step-by-step development of the coherence between behavioural biology concepts, and the introduction of the stress mechanism as a tool for inducing coherence between the perspectives of Tinbergen and different levels of biological organisation (5.3.4).

5.3.3 Using concept maps

Models of behaviour are particularly used in (educational) psychology (see e.g. Huit, 2009), but also in behavioural biology (see figure 8). Models as simplified representations of the real world could be used for representation of the relations between concepts in a complex system (Ossimitz, 2000). Because of the strong causality of behaviour (with the emphasis on internal and external stimuli), the ability of thinking in dynamic processes is also an important criterion for representing concepts in behavioural biology. Ossimitz (2001) describes several ways of building such representations, e.g. causal loop diagrams (feedback loops), verbal description and stock-and-flow diagrams. For behavioural biology education, we have to search for a type of representation of behavioural biology that supports the before-mentioned dimensions.

Since the publication of a special edition of the Journal of Research in Science Thinking in 1990 showed the importance of concept mapping (Al-Kunifed & Wandersee, 1990) a considerable amount of research has validated the usefulness of creating concepts maps in meaningful science teaching and learning (Kinchin I. M., 2001; Gouveia & Valaderes, 2004; Aguilar-Tamayo & Aguilar-Garcia, 2008; Wallace & Mintzes, 1990). Concept maps promote students' meaningful learning, and enhance the integration and retention of knowledge (Mintzes, Wandersee, & Novak, 1997). In addition, concept mapping is frequently used by researchers in education as an instrument to investigate students' mental models (Chang, 2007; Kinchin, 2001). Therefore, in line with the Vygotskian view of meaning construction (chapter 2), we decided to use concept maps to represent of behavioural biology.

A concept map is a graphical representation for the organization and representation of knowledge (Novak & Cañas, 2008). The core element of a concept map is a proposition, which consists of two or more concepts connected by a labelled link. The linking phrase specifies the relationship between the concepts. Concepts are mental representations allowing the individual to recognize and categorize events and objects (Aguilar-Tamayo & Aguilar-Garcia, 2008). In a concept map, propositions are connected to each other to form a hierarchical structure that represents the organization of knowledge in long-term memory (Novak & Cañas, 2008). The basic assumption of the concept map is that interrelatedness is an essential property of knowledge.

How can we build a coherent web of concepts of behavioural biology? We identify three steps:
1. Determine the basic causal loops;
2. Conceptualize the causal loops;
3. Expand the conceptualization by elaboration of the concepts.

First, thinking in interrelated structures, we determine the basic causal loop of behaviour: the interaction between an organism and its environment (figure 13).

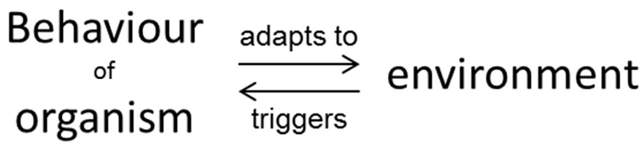

Figure 13. Basic causal loop of the interaction between an organism and its environment.

The second step is to construct a concept map by adding the behavioural biology concepts as is shown in figure 14.

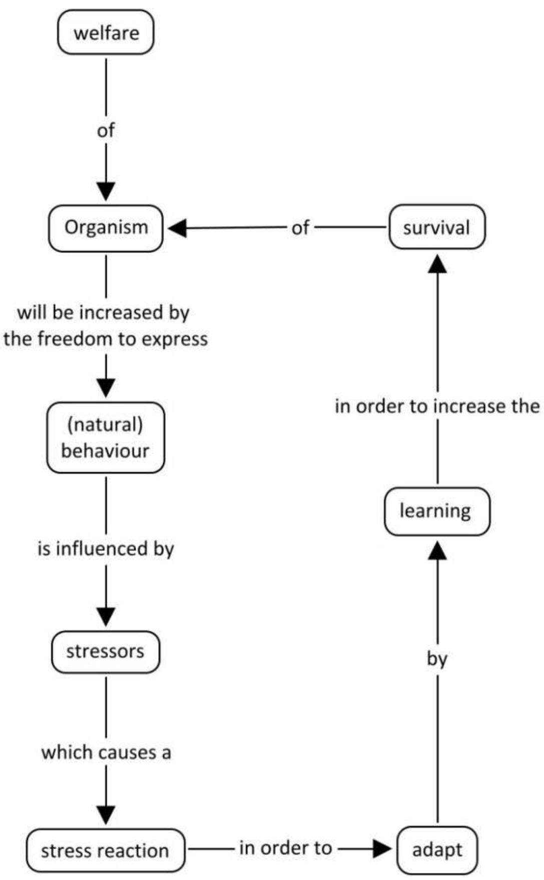

Figure 14. Basic concept map of behaviour of an organism.

This concept map could serve as the basis for evaluation of students' coherent understanding of behavioural biology when they are asked to construct concept maps as a reflection assignment.

It could be discussed whether the concept SURVIVAL should be replaced by the concept FITNESS, but according to the basic causal loop, the use of the concept SURVIVAL fits better than the concept FITNESS. The behaviour of an organism is aimed at survival, while the concept FITNESS is classified under the evolution of behaviour. Our prior study on students' ideas about behaviour showed that students do not have any notion about the evolution of behaviour (Van Moolenbroek, Boersma, & Waarlo, 2007), and even the benchmark of Project 2061 omits the evolution of behaviour. In addition, evolution is seen as a biological key concept (Boersma, et al., 2005), and to understand the evolutionary perspective of behaviour students have to understand the concepts of evolution as well. However, in the current educational practice we could not rely on the correct understanding of the concepts of evolution. Therefore, it is questionable if it is wise to learn and teach the evolution of behaviour apart from the other concepts of evolution. Thus, when teaching behavioural biology is aimed to make students aware of behaviour, it is for sake of reducing complexity (and avoiding curricular overload) that we leave the learning and teaching of the evolution of behaviour aside, and speak from here on about the three perspectives of Tinbergen, instead of four.

The third step in building a coherent web of concepts is to expand the conceptualization by elaborating concepts as STRESS REACTION, LEARNING, SURVIVAL, and WELFARE. These concepts are listed in table 6, except the STRESS REACTION. The stress reaction is the connection between the functional and causal perspective. When an organism cannot express normal (natural) behaviour, it experiences stress. Stress is defined as an organism's total response to environmental demands or pressures. Studying the influence of INTERNAL AND EXTERNAL STIMULI on behaviour, one unavoidably encounters the phenomenon of STRESS. Stress could be recognizable and relevant for students because of its ubiquitous nature. Everybody experiences stress, which should be inherently understandable from the definition of behaviour. Therefore, the stress reaction, or the STRESS MECHANISM, is not only relevant, it could also serve to induce coherence in the web of behavioural biology concepts. The stress mechanism connects behavioural biology with physiology and psychology.

Although an overload of concepts should be avoided, we think it is necessary to include the stress mechanism in behavioural biology education, and consequently in the concept map. The stress mechanism will be explained in section 5.3.4.

Finally, building a coherent web of concepts for behavioural biology education as shown in figure 14 must be expanded with the concepts needed to explain the stress mechanism. This final concept map is presented in figure 15.

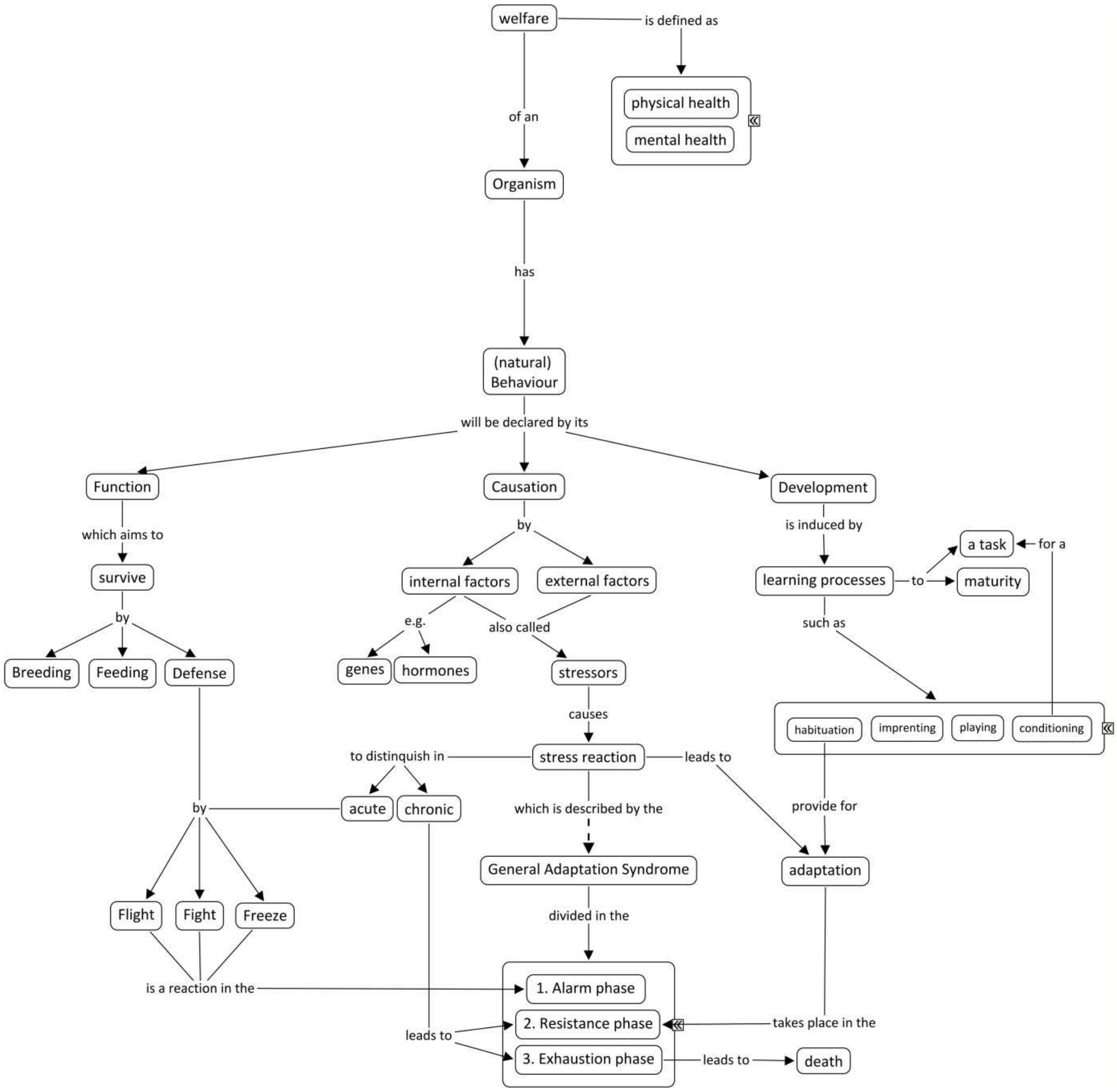

Figure 15. Expanded and final basic concept map for behavioural biology education.

5.3.4 The stress mechanism

When the phenomenon stress was studied, the term was initially used to denote both the causes and the experienced effects of pressures. More recently, however, the concept STRESSOR has been used for the stimulus that provokes a stress response[14]. In 1936 the Canadian endocrinologist Selye published his first ideas about the General Adaptation Syndrome (GAS). He introduced the word STRESSOR for the causative agent, retaining the term STRESS for the resulting condition (Selye, 1978), to distinguish the concepts STRESS and STRESSOR. He observed the syndrome as a whole, representing a generalized effort of the organism to adapt itself to new conditions (Selye, 1936), and stated that

> "Adaptability is probably the most distinctive characteristic of life" (Selye, 1978, p. 159).

Selye defined the GAS as the process that describes

[14] Stress. (n.d.). *Encyclopedia of Medicine*. http://www.answers.com/topic/stress (Retrieved January 2010)

"the non-specific response of the body to any demand" (Selye, 1978, p. 55),

which means that the stress mechanism is a physiological process. Therefore,

"stress is the state manifested by a specific syndrome which consists of all the non-specifically-induced changes within a biologic system." (Selye, 1978, p. 64).

The General Adaptation Syndrome progresses in three stages, which are illustrated in figure 16.

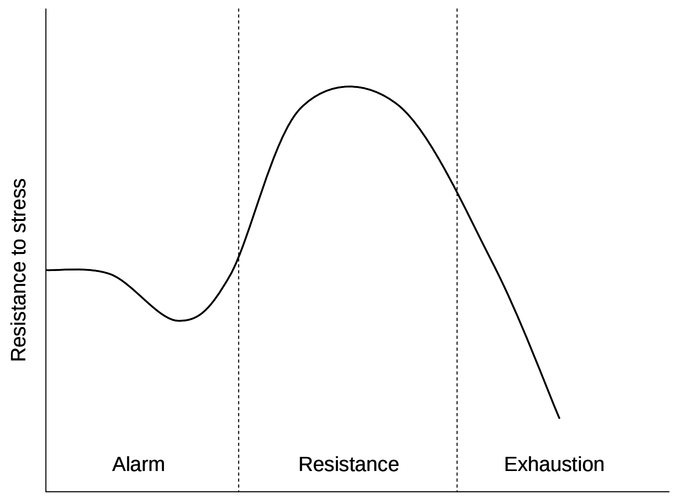

Figure 16. Illustration of the General Adaptation Syndrome, using general resistance to an injury as an indicator. (adapted from Selye, 1978, p. 111)

In other words, stress is how the body physiologically prepares and answers to change.

"Anything that causes stress endangers life, unless it is met by adequate adaptive responses; conversely, anything that endangers life causes stress and adaptive responses. Adaptability and resistance to stress are fundamental prerequisites for life, and every vital organ and function participates in them." (Selye, 1950, p. 1383).

The stress response expires via two different axons: a fast reaction of the autonomic nervous system and a slow reaction via the hypothalamic-pituitary-adrenal axis (HPA axis) (see figure 17). In the fast reaction, the hypothalamus activates the autonomic nervous system to release the stress hormones (nor) adrenaline. Adrenaline and noradrenaline are emitted through adrenal. A higher heart rate and blood pressure is the result, so blood supply to the muscles and brains increases. The organism is able to react alertly: fight or flight. The alarm response is the first stage. When the threat or stressor is identified, the body's stress response is a state of alarm. Afterwards, the stress level can be measured via blood plasma or urine.

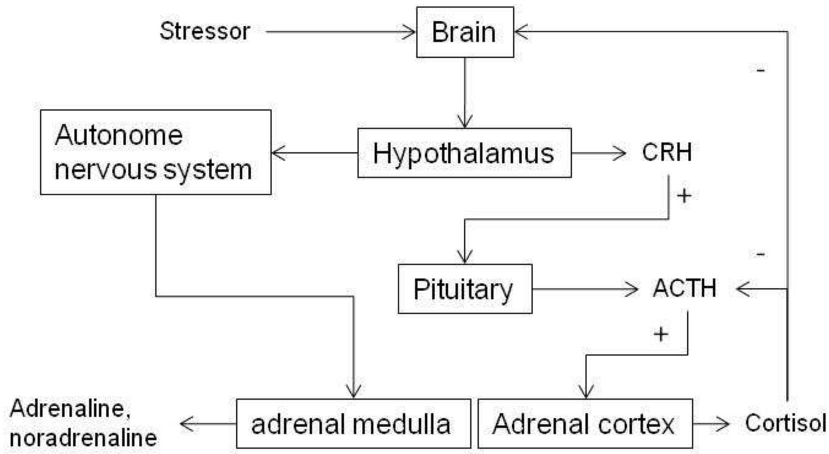

Figure 17. Schematic representation of the two body responses to a stressor. (From: https://en.wikipedia.org/wiki/Hypothalamic-pituitary-adrenal_axis Retrieved February 2012)

The slow stress response runs via the release of hormones. Corticotrophin-releasing hormone (CRH) is released by the hypothalamus. CRH stimulates the pituitary to produce adrenocorticotropic hormone (ACTH). ACTH stimulates the adrenal cortices, which produce glucocorticoid hormones (mainly cortisol in humans). Glucocorticoids in turn act back on the hypothalamus and pituitary (to suppress CRH and ACTH production) in a negative feedback cycle. The stress hormone cortisol is aimed to slow down the strength action of adrenaline. Although the body begins to adapt to the strains or demands of the environment, the body cannot keep this up indefinitely, as its resources are gradually depleted. One could become insane when there is no decline in stress. Cortisol breaks down the proteins in the muscles, and so the body gets energy. In a stress reaction, the body produces ten times more cortisol than usual. Consequently, people feel energetic. Cortisol also limits the amount of white blood cells, suppressing the immune system. Due to a high amount of cortisol, the brains diminish the release of CRH: a feedback loop. Cortisol is measurable in blood, urine, and saliva. In the resistance stage, the body recovers from the reaction in the alarm phase. Experimental studies in rats have revealed many different types of stress, physical, social, or mental stress. Stressors can be of many different types, but both types activate the HPA axis (Johnson, Kamilaris, Chrousos, & Gold, 1992).

Exhaustion is the third and final stage of the GAS model. At this point all the body's resources are eventually depleted and the body is unable to maintain normal function. Exhaustion happens when the feedback system is out of control and high levels of cortisol remain. The initial autonomic nervous system symptoms may reappear (sweating, raised heart rate, etc.). If stage three is extended, long-term damage may result as the capacity of glands, especially the adrenal gland, and the immune system are exhausted and the function is impaired resulting in decompensation. A chronic overreaction to stress overloads the brain with powerful hormones that are intended only for short-term duty in emergencies. Their cumulative effect damages and kills brain cells, especially in the hippocampus, which is sensitive to cortisol. The hippocampus plays a role in memory, and especially in the memories of stress situations. We feel, therefore we learn (Immordino-Yang & Damasio, 2007).

The GAS can be viewed not only physiologically, but also behaviourally. In the alarm phase, the body shows the changes characteristic of the first exposure to a stressor. At the same time its resistance is diminished and, if the stressor is sufficiently strong (e.g. extremes of temperature), death may result. Behaviourally, the alarm reaction could be ‘fight, flight or freeze’. The organism has to choose: fight, flight or freeze to save life. Obviously, senses and emotions play an important role and stress has much impact on learning and memory (O'Halloran & O'Halloran, 2001; Cahill, Gorski, & Le, 2003; Yonelinas, Parks, Koen, Jorgenson, & Mendoza, 2011).

In the second phase, resistance increases when continued exposure to the stressor is compatible with adaptation. The defence is twofold: overcompensation and coexistence. The bodily characteristics of the alarm reaction have virtually disappeared, and resistance to a stressor rises above normal (overcompensation). Even when an organism habituates, the bodily signs disappear and the body recovers from the acute stress reaction.

In the exhaustion phase, triggered by long-continuing exposure to the same stressors to which the body had become adjusted, exhaustion follows, resulting finally in the death of the organism. The signs of the alarm reaction reappear, but now may be irreversible, and the individual may experience symptoms of adrenal failure. At this stage, humans experience chronic stress, which is known as a burnout.

The GAS demonstrates a strong relationship between behaviour and physiology and even psychology. Influenced by environmental factors and internal physical organization, an organism adapts and has learning experiences. Organisms adapting insufficiently will not survive. Consequently, he who learns survives. Therefore, learning and teaching about learning processes should be considered as an inseparable part of teaching behavioural biology. Learning processes always take place in interaction with the environment and are influenced or limited by the capabilities of an organism.

Stress is not only negative. Selye distinguished two types of stress: eustress (positive) and distress (negative). Furthermore, according to our common sense we know that pressure leads to performance, but too much pressure to depression. This principle is known as the Yerkes-Dodson principle (figure 18).

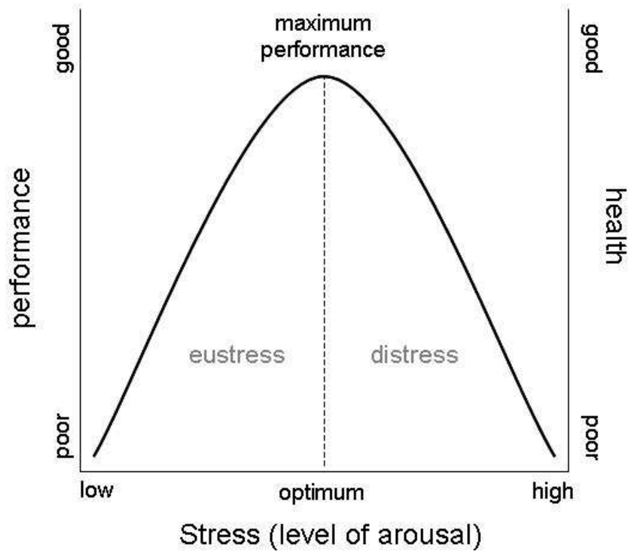

Figure 18. Influence of stress to performance, known as the Yerkes-Dodson principle. (Adapted from Wikipedia, https://en.wikipedia.org/wiki/Yerkes-Dodson_law, Retrieved February 2012)

5.4 Learning objectives for behavioural biology education

In this study our main goal is that students are aware of behaviour, which is the basic level of behavioural literacy. In addition, the following learning objectives for behavioural biology education are formulated.

Students are able

1. to explain that behaviour is caused by internal and external stimuli;
2. to describe that behaviour is the result of the interaction between the organism and its environment;
3. to determine the function of behaviour;
4. to describe the development of behaviour;
5. to recognize the stress mechanism in the behaviour of humans and animals;
6. to carry out a simple behavioural research (only at pre-university level);
7. to discuss applications of behavioural research in vocational and scientific practices.

Over time and cultures, the most robust and most effective form of communication is the creation of a powerful narrative - Howard Gardner

6 Towards an LT-strategy for 'behaviour'

6.1 Introduction

Chapters 2 and 4 yield the design criteria for an LT-strategy for behavioural biology. In chapter 2, we described our view on learning and teaching, and educational design criteria for an LT-strategy were defined. We integrated two educational approaches: the concept-context approach and the problem-posing approach. In the fourth chapter, content criteria for learning and teaching behavioural biology were described.
In this chapter, we describe the development of an LT-strategy for behavioural biology. In section 6.2 the design criteria and learning objectives are elaborated for a global design of the LT-strategy. In section 2.4 we described three building blocks for an LT-strategy: the use of authentic social practices, interaction, and the evoking of motives. Therefore, in section 6.3 we justify the choices for authentic practices. Section 6.4 makes clear how interaction is planned, and in section 6.5 we describe how motives can be evoked.

Starting point for the description of the LT-strategy is the second version of the strategy, while adaptation from the first to the second version is seen in retrospect.

6.2 Global design for an LT-strategy for behavioural biology

The findings of the explorative phase and the domain-specific philosophy of learning and teaching behavioural biology resulted in criteria for designing an LT-strategy, which can be divided into criteria for the learning and teaching processes and criteria for behavioural biology. In chapters 2 and 4, the following design criteria are formulated:

1. An LT-strategy for behavioural biology should be based on behavioural biology concepts used in authentic *social practices*. Authentic means existing in social reality. The behavioural biology concepts should be elaborated and students should have the opportunity to explore their personal, societal, and/or scientific relevance.

2. Participation in a social practice motivates learning as the outcome of *interaction* between a person and his/her environment. An LT-strategy for behavioural biology must promote interaction between learners and their learning environment in an educationally appropriate social practice.

3. Learning activities must promote the thinking processes of students. Therefore, an LT-strategy for behavioural biology must evoke *motives* or one or more steering questions. The sequence of LT activities must provide a story line and create opportunities for non-interrupted learning.

4. *Recontextualising* of earlier acquired concepts is not self-evident when other practices are introduced, and should be incorporated explicitly in the LT-strategy. This implies that an LT-strategy should consist of more than one practice.

5. An LT-strategy should be based on *21st century* behavioural biology, which means at least that *links* must be made with other biological disciplines such as physiology, genetics, and psychology.

6. Students should be aware that behaviour emerges in a dynamic and complex system, which results from multiple causes and develops through the interaction of the organism with its environment. Therefore, an LT-strategy should emphasise *systems thinking* to achieve awareness of behaviour and coherence between concepts.

7. The behavioural biology concepts in an LT-strategy should be *structured* according to the perspectives of causation, development, function, and evolution of behaviour.

8. An LT-strategy should pay attention to the social *relevance* of behavioural biology in order to develop students' understanding of its relevance.

An LT-strategy, based on the aforementioned design criteria, has an intentional learning outcome, which is defined in learning objectives. In this study, the main goal is to make students aware of behaviour. Consequently, the intended outcome of the strategy is that students are able:

1. to explain that behaviour is caused by internal and external factors,
2. to describe that behaviour is the result of the interaction between the organism and its environment,
3. to determine the function of behaviour,
4. to describe the development of behaviour,
5. to recognize the stress mechanism in the behaviour of humans and animals,
6. to carry out a simple behavioural research (only at pre-university level),
7. to discuss applications of behavioural research in vocational and scientific social practices.

Outline of the LT-strategy
Figure 19 shows the outline of the LT-strategy, which starts with evoking the central steering question in behavioural biology: "Why does a human or animal do this?" This question can be answered from Tinbergen's perspectives on behaviour. The central steering question should focus students on the educational social practices that will be explored (design criteria 3 and 7).

The global design of the strategy consists of three practices and each practice starts with a steering question. A steering question will be derived from the activity of the authentic practice (design criteria 1, 2, and 4).
Furthermore, the three stages of the problem posing approach (questioning, activity, reflection, see section 2.4.1) are embedded into the strategy. Consequently, the sequenced practices have different

educational aims (Westra, 2008). After evoking the central steering question in the focus lesson, the LTAs of the first two practices are meant for answering the central steering question, while the last practice (testing) can be seen as a reflection phase. The first and second practice are aiming to enlarge students' prior knowledge on behavioural biology with new knowledge, whereby the concepts acquired in the second practice form an extension of the concepts from the first practice. The third practice is meant to test students' knowledge on behavioural biology (design criterion 4).

In addition, each practice, including the focus lesson, is also built up according to the problem posing approach. A reflection phase follows each LT-activity phase, wherein students look back to the steering question of the practice and to the central steering question. After that a new steering question will be evoked, which makes it plausible to change to a new practice.

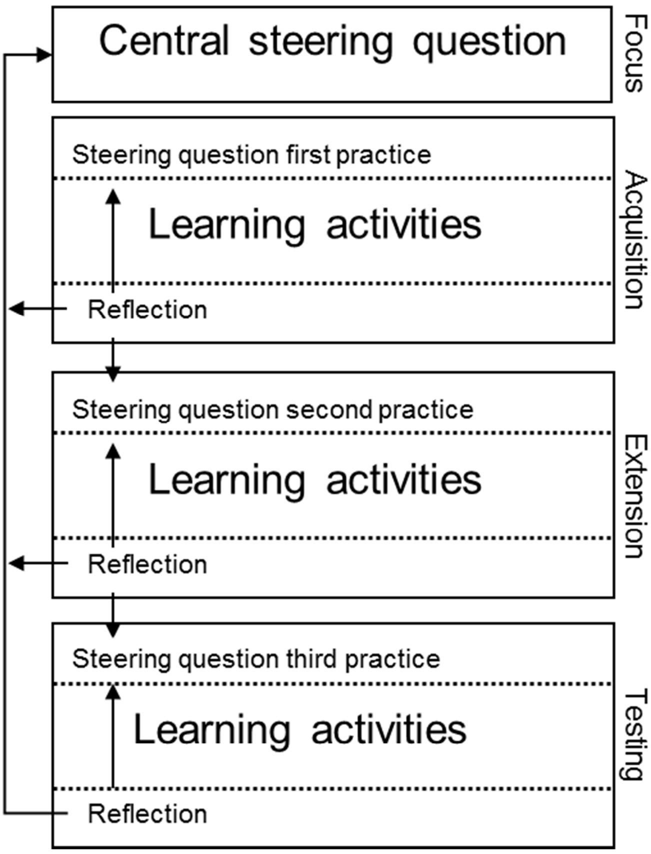

Figure 19. Outline of the global LT-strategy (adapted from Westra (2008)).

6.3 Selection of authentic social practices

Because of interaction, behaviour appears. So, behaviour could be explored in any practice where organisms are objects or subjects (see also the definition of behaviour, section 4.2). However, for education it is prudent to select practices wherein selected behavioural biology concepts could be recognised easily. As noted in section 2.4.2, three categories of practices can be distinguished: life-world, professional practices and scientific practices. For this LT-strategy, we have selected four authentic social practices. The first and third practices are the same for students at vwo and havo level. For the second practice, a distinction is made between havo and vwo level, and this practice differs in topic, category, and level (practices 2a and 2b).

For the LT-strategy, we selected four authentic social practices:

Practice 1 Caring for your pet (dog) [orientation]
Practice 2a Designing a welfare friendly stable for thousands of pigs [exploration]
Practice 2b Researching the overtraining syndrome [exploration]
Practice 3 Dealing with aggressive people [testing]

6.3.1 *Criteria for selection of authentic social practices*

The level of the lesson series is determined through the interplay between the authentic social practice and students' educational needs. In fact, authentic social practices could be seen as complex systems with many relationships, wherein execution of activities supposes experts' knowledge, while it is an educational need to bring the social practice into the students' zone of proximal development. In the activity theory social practices are analysed by six elements: subject, object, instruments, rules, community and task allocation (Van Eijk, Goedhart, Kaper, & Ellermeijer, 2004). Therefore, an authentic social practice should be adapted and made suitable for education, and we require criteria for the selection of authentic practices. In addition, the question should be answered which restrictions or points of attention must be considered to make practices suitable for teaching and learning behavioural biology. Why or when are authentic practices suitable for biology education? In retrospect, the criteria for evaluation of the suitability of authentic practices can be divided in two categories: two behavioural biology (content) criteria and three educational criteria. These five criteria are discussed successively.

1. Aims of behavioural biology

Animal behaviour research contributes in three domains of human society: animal welfare, conservation of species, and understanding of human nature (Bolhuis & Giraldeau, 2005). Therefore, the first content criterion is whether an authentic social practice meets one or more of the aims of behavioural biology. Authentic life-world, professional, and scientific practices satisfying this criterion, can be found.

> "One area in which studies of causation have been particularly numerous is in the field of applied ethology. Most of these studies seek answers to practical problems that confront farmers and others who raise animals commercially or people who keep animals as pets." (Hogan, 2009, p. 43).

All selected practices meet one of the objectives of behavioural biology. In practices 1 and 2a, welfare of animals is the aim of the activities, while practice 2b focuses on both the understanding of human nature and the welfare of animals. Obviously, the test practice about aggression deals with the understanding of human nature. Conservation of species is not elaborated in the practices, but it is supposed that this objective could successfully be explored in a practice such as the zoo.

2. Levels of biological organization

The fifth design criterion requiring that behavioural biology should be linked to other biological disciplines such as physiology implies that it must be possible to introduce the molecular level of biological organization. The molecular level is required in order to include the functions of hormones in the causal explanation of behaviour. Examples of hormones functioning as components of the stress mechanism are adrenaline and cortisol. Adrenaline is a well-known hormone, which is used in case of acute stress situations. Therefore, adrenaline can be used in a life-world practice. However, in life-world language it is not necessary scientifically clear. In contrast, the functions of adrenaline and cortisol are especially studied by endocrinologists. Therefore, introducing the molecular level requires the selection of a scientific practice. However, at havo level we do not use authentic scientific social practices. Therefore, in the LT-strategy introducing the General Adaptation Syndrome ‘embedded scientific practices’ are included. Embedded practices will be explained in section 6.3.3.

3. Practices should elicit motives

In chapter 2 we argued that meaningful learning requires functional knowledge. In the case of meaningful learning students are able to connect new knowledge with their prior knowledge. New knowledge becomes more functional when it is relevant, and when it enables a learner to participate adequately in a social practice (see figure 1). Furthermore, we argued that adequate participation in a practice is possible when motives for action are elicited, and problem solving could evoke a motive for the execution of activities in a practice. Therefore, problem solving should be a central issue in the selected practices, and, according to the Cultural Historical Activity Theory (CHAT), the nature of the activity of the social practice should be the leading principle for the evaluation of the educational applicability of a social practice. Problem solving LT-activities should meet ‘the willingness to act’ (see section 2.3), and therefore, increase students’ motivation to learn.

In the intended curriculum the steering question of a practice is the leading motive:

Practice 1 How to *care* for your pet?
Practice 2a How to *design* a welfare friendly pig stable?
Practice 2b How to *research* the overtraining syndrome?
Practice 3 How to *deal* with aggressive people?

The question of how the problem posing cycle is elaborated in the LT-strategy will be discussed in section 6.5

4. Reducing complexity

For an adequate understanding of behavioural biology concepts, it is not desirable to use all concepts and relationships between concepts applied in an authentic social practice in one educationally adapted practice. In chapter 4 we argued for a minimum of behavioural biology concepts that should be taught. Therefore, complexity has to be reduced, and the possibility to reduce the complexity of an authentic practice without losing essential elements for behavioural biology education is another criterion for selecting authentic practices. Reducing complexity should be directed by the sequence of LTAs - the storyline -, because each LTA covers a part of the content. Looking backwards, for reduction of the complexity in the intended curriculum we distinguish two practical techniques.

First, a causal loop directs the sequence of LTAs, as we explained in figure 14. This sequence is structured according to the perspectives of Tinbergen (design criterion 7). Focusing on the behavioural biology concepts and ignoring other concepts diminishes the complexity. The selection of behavioural biology concepts and the description of its coherence are described in section 5.3.

Second, role-playing, conform the activity of the practice, may result in students' recognition of the necessary skills and a need to know how to acquire these skills. Role-playing provides students the opportunity to empathize with a situation, person and perspective. In the case of collaboration, different roles show students different perspectives in problem solving. By choosing adequate roles other possible roles in the practice may be omitted, which reduces complexity.
In the scenario, the following roles were selected:

- dog owner (practice 1)
- (pig) farmer, economist, animal protectionist and researcher (practice 2a)
- researcher (practice 2b)
- police officer, behavioural biologist (practice 3)

Practice 2a includes more roles than the other practices, because the activity 'designing' is performed by students in a multidisciplinary team, wherein they have to collaborate in order to design a welfare friendly pig stable. In the practices 1 and 2b the role of a dog owner and a researcher result from the perspective of the practice, represented by the central steering questions. In the third practice, students have to focus on the practice of a police officer who has to deal with aggression. However, in their role of a behavioural biologist students have to give advice on how to deal with aggression in an adequate manner. Since it can be supposed that a role is the central figure in a story, it may be also an indispensable element in an educationally adapted authentic practice.

5. Availability of authentic material

Authentic materials, such as research data, videos and articles, are necessary for production of learning materials. Finding original materials is not difficult: the internet is a rich source of data. Nearly all of our sources for the learning material were collected from the internet, except research data, which are usually not published on the internet.

The collected materials were adapted for education to fit into LTAs. Articles were adapted, for example to avoid informal language, to meet students' level of understanding, and to restrict the texts (language, level, and length). An important condition is that those articles correspond with the type of practice: life-world, professional or scientific. Students were required to explore each text with a set of questions, aiming to lead students through the texts, while paying attention to behavioural biology concepts.

Also videos were found, most of them from the internet. Some videos are a broadcasted tv-reportage, and owners are inclined to make them available for education. Important contributions were the research videos of horse behaviour, received from researchers of Utrecht University, Faculty of Veterinary Medicine. They were so kind to search for the videos with the best visible differences between the controls and (over)trained horses. In addition, relevant data of heart rate and heart rate variability were delivered.

6.3.2 Educational description of the selected practices

In this subsection we describe the selected practices. Attention is paid to the relationships with the selection criteria: the behavioural biology aim, the steering question, educational adaptation, the storyline, and the use of authentic materials.

Focus lesson

The first lesson is aiming to take away students' matter of course of behaviour, and to evoke interest in finding an explanation of it: "Why does he do it?" Therefore, the story starts with the unexpected behaviour of a dog, as a preparation to the first practice. Students explore the central steering question from the three perspectives (causation, function, and development of behaviour) by reading an article about dominant and submissive behaviour of dogs. We selected the practice for the focus lesson as a part of the first practice to allow a non-interrupted transition from evoking the central steering question to the steering question of the first practice.

Practice 1: Taking care of your pet

To increase awareness of behaviour (design criterion 6), we selected a first practice in the category life-world: taking care of your pet, with a dog as an example. People love their pets (Archer, 1997) and most students in secondary education have experiences with pets (Van Moolenbroek, Boersma, & Waarlo, 2007). Therefore, this practice is relevant and suitable for students.

Pets should be cared for. Therefore, the steering question of this practice is 'what do you have to know to care well for your pet?' 'Caring' is the central activity in this practice and it includes all other activities, such as feeding, housing, and nurturing (design criterion 3). Students are asked to answer the steering question of the practice by executing a number of LTAs, although the steering question is not asked explicitly. In the reflection phase of practice 1 in the first research cycle the steering question of the practice is connected with the central steering question of the whole lesson series "Why do they do that?"

> "The main question was: 'what does behaviour mean?', or: 'why do they do that?' We have searched for answers on that question by taking care of your pets. What do we have to know to care for our pets?" [1, Learning material, practice 1, LTA$^{4.2}$][15]

In the reflection phases of the learning material in the second research cycle, the students are asked to answer the following question:

> "In the reflection phase you reflect on what you have learnt about behaviour. Which concepts are used in the previous lessons?" [2, Learning material, practice 1, LTA$^{5.1}$]

The story of the practice starts with the observation that pets are dependent of humans. Thus, humans are responsible for the welfare of their pets. Thereafter, students have to discover what welfare means. Feeding, housing and breeding are examples of activities that are directed to the welfare of a pet, but when and how can you see that a pet is 'happy'? The most common definition of animal welfare is 'the physical and mental health of an animal.' In 1998, the European Union declared five freedoms for animal welfare (EU, 1998) (see chapter 4).

In addition, pets show three functional classes of natural behaviour: feeding, reproduction and defence, and students explore the function of behaviour by describing natural behaviour of pets such as a dog, a

[15] See section 7.2 for explanation of the code of the fragments, and chapter 8 for an overview of the LTAs.

cat, and a rabbit. The ultimate function of behaviour is of course to survive. However, when a pet is not able to show natural behaviour, stress arises. This issue is introduced in the learning material with an article about dog stress. Stress is caused by stressors (internal and external factors or stimuli). Hormones such as testosterone and cortisol are examples of internal factors (design criterion 5, 7). The defence against stressors runs according to the General Adaptation Syndrome (Selye, 1950; 1978). In the alarm phase a pet reacts with fight, flight or freeze, which is observable behaviour. When a stressor persists after the alarm phase, pets have to adapt their response (adaptation phase). When adaptation fails, a pet dies (exhaustion phase). Learning processes, the vehicle of adaptation and the resulting development of behaviour, could be distinguished in two ways, namely the development of behaviour from juvenile to adult and the development of behaviour influenced by nurture (education). This construction also meets design criterion 5.
In the first practice, some internet articles and YouTube videos are adapted and embedded in the learning materials.

Practice 2a (havo): Designing a welfare friendly pig stable
The second practice at the havo level is a professional practice, since havo prepares students generally for vocational education (design criteria 1 and 6). The steering question of this practice is how to design a welfare friendly pig stable.

Farm animals are kept for production instead of for company like pets. However, welfare is a salient topic for both pets and farm animals. Also farm animals show natural behaviour, but the way they are kept has much influence on the performance of their natural behaviour, and consequently on their welfare (design criterion 3). The number of stressors and the ability to adapt (cope) influence the level of welfare.
In building a stable where animals can express their natural behaviour as much as possible, the question arises how the amount of stress could be measured. Answering this question leads to an understanding of the physiology of the stress mechanism (design criteria 5, and 7). Stress negatively influences the growth and resistance of farm animals against diseases, so optimization of the production environment is necessary. Therefore, the final assignment for students in the educational adaptation of the practice is to design a 'pork plaza', a mega stable for thousands of pigs, where pigs experience low levels of stress (design criteria 2 and 3). In addition, videos of scientific research on the stress of pigs and internet articles are adapted and used as learning materials.

Practice 2b (vwo): Researching the Overtraining Syndrome
In the first research cycle students from pre-university classes commented that the level of executed curriculum was not challenging. Therefore, in the second research cycle another practice about researching the overtraining syndrome (design criterion 1) was selected.
At Utrecht University endocrinological and behavioural adaptations to experimentally induced physical stress in horses was investigated (De Graaf-Roelfsema, 2007). Horses were trained with a treadmill over a period of 32 weeks, whereby the intensity of the training varied. One group of horses underwent a regular training intensity, while the other group got a more intensified training program and became overreached. Data were collected during the training, both physically (e.g. blood

examination, muscles biopsies, heart rate variability, hormone levels) and behaviourally. In a Novel Horse Test (NHT) horse behaviour was observed by means of video surveillance. This test was a specially developed assessment to challenge the horses for a novel situation. A horse was led into a prepared indoor arena and was free to explore it. After 5 minutes a novel horse was presented, separated by a fence. Both animals were allowed to interact freely over the beam. After 5 minutes the novel horse was led away and the observed horse was left alone for another 5 minutes. Behavioural research showed clear differences between the control horses and the test horses. The overtrained test horses, showed obviously less interest in their environment and in other horses. (Van Dierendonck, et al., 2007).

This research is very suitable for educational aims, because of its relevance for exercise, horses, and humans. It is also relevant for society, because it is connected with the burnout syndrome and exercise, and for science, because it is important to find possible markers for the detection of early overtraining (design criteria 1 and 7). Other arguments are the strong connection between the behaviour of horses and their physiological components (criterion 7) and the availability of authentic research data (video) of the behaviour of horses.

Although it is possible to adapt this research for educational purposes, stimulating a motive for students to research overtraining was not easy (design criterion 3). Therefore, we started with the students' experiences with stress. What thoughts students have and, which behaviour and physical symptoms do students show when they are stressed? Students learn about three categories of stressors: mental, emotional and physical. From here, the attention of students is led to exercise as a physical stressor and the overtraining syndrome as a real problem. The necessity of recognizing overtraining at an early stage is raising the question whether stress is measurable (design criterion 3). To answer this question, knowledge about the physiology of stress (design criterion 7) and an acceptable test animal are needed. With the authentic views on healthy and overtrained horses, a behavioural research could be performed in the classroom (design criterion 2).

There are at least two difficulties with this practice. First, to evoke the steering question, it seemed necessary to embed life-world and professional practices within this scientific practice. Second, it seemed to be difficult to make a clear distinction between the three perspectives of Tinbergen. These difficulties and their consequences are elaborated in more detail in the sections 6.4-6.6.

In addition to internet articles, authentic research videos from the Novel Horse Test were provided by the researchers. With the video material students must be able to do a small behavioural study.

Practice 3 (havo, vwo): Dealing with aggressive people

The last practice is aiming to test whether students are able to use their acquired knowledge in an unknown practice. In this practice, instead of animal behaviour, the object is human behaviour and the topic is aggression instead of stress. Aggression is a commonly occurring reaction, and is a form of defence against stressors (fight). Therefore, it is relevant for students to know about and study aggression. One of the goals of behavioural biology is to understand human behaviour. So, the change

to human behaviour is made with this practice.
This practice is adopted from the work of Adang, a behavioural scientist working at the Police Academy of the Netherlands and specialized in aggression (riots). His research focuses on the interaction between police and civilians in a variety of potentially dangerous conflict situations (Adang, 2009).
A police officer is a person who regularly faces aggression and has the authority to use violence. How does a police officer deal with aggression and what does he know about (the prevention of) aggression? Furthermore, the police have to deal with group aggression; riots during football matches are a well-known example. What could a behavioural scientist contribute to the prevention of riots? Students have to adopt the role of a behavioural scientist. With the acquired knowledge from the previous practices and an original written observation about a confrontation between the police and football hooligans, students have to write an article about the question how the police have to deal with aggressive people and to anticipate on riot situations.

Although the description of the third practice is from the second research cycle, it must be noted that the test practice in the first research cycle consisted of a written test about the topic aggression, because there was not enough lesson time to explore the practice more extensively.

6.3.3 The use of embedded practices

In section 6.3.1 we argued for the use of embedded practices to introduce scientific concepts at the molecular level, and to construct a non-interrupted storyline. We define an embedded practice as a (part of a) practice that is necessarily placed into the elaboration of another practice to create a non-interrupted storyline. Therefore, an embedded practice is preferably elaborated within one LTA and has to elicit a motive for a new steering question, or provide for necessary knowledge. In this section, we elaborate how and why we use embedded practices in our LT-strategy. Figure 20 shows where embedded practices are located in the LT-strategy.

Focus lesson Embedded practice 1 'the need for behavioural research'	
First practice Embedded practice 2 'The General Adaptation Syndrome'	
Second practice – havo Embedded practice 3 'Researching stress in pigs'	**Second practice – vwo** Embedded practice 4 'Stress in daily life' Embedded practice 5 'Overtraining in the exercise
Third practice Embedded practice 5 'Senseless violence by a child'	

Figure 20. Overview of the place of the embedded practices in the LT-strategy

In the LT-strategy we use embedded practices for three purposes.

1. Embedded practices were used to provide for motives or steering questions to create a continuing storyline. For example, in the first practice, the causal perspective of behaviour is introduced in an article about dog stress. Students learn about the interaction between the environment and the organism, which evokes the question 'how stress works?' Research on the stress mechanism is a scientific practice, but its introduction in the first practice in the article (about the stress mechanism) in the workbook has the nature of a historical resource about the discovery of the mechanism by Selye. This article is embedded in the storyline, because the steering question evokes from the former LTA[3.1] about the dogs' stress, asking how stress works. Thereafter, a short article about scientific research on the behaviour of dogs, human interaction and cortisol follows:

> **"Human interaction and cortisol: Can human contact reduce stress for shelter dogs?**
> Animal shelters are an extremely stressful environment for a dog, most specifically due to social isolation and novel surroundings. The stress response of dogs housed in this environment may be alleviated through human interaction shortly after arrival. During their second day in a public animal shelter, some adult stray dogs were engaged in a human contact session, and some were not. The session involved taking the dog into an outdoor enclosure, playing with the dog, grooming, petting, and reviewing basic obedience commands. Each dog interacted with a human for approximately 45 minutes. Salivary cortisol levels were examined from each dog on their 2nd,

3rd, 4th, and 9th day of housing. Animals that were engaged in a human contact session had lower cortisol levels on day 3 than animals that did not. Breed type, sex, and age did not have an effect on cortisol levels on any day measured. A human interaction session can be beneficial to both animal welfare and adoption procedures. The current study not only utilized the human contact session as a treatment to reduce stress but also as a resource for individual temperament/personality information that could be later used to facilitate compatible adoptions. Human interaction may be an effective means of reducing the cortisol response of dogs in the aversive shelter environment." (Coppola, Grandin, & Enns, 2006, p. 537).

This article is an example of the role of cortisol in the stress mechanism, and a new steering question is developed, namely, how a dog could adapt to stressors. With this steering question, a connection to the next perspective of behaviour (development) is elaborated. Therefore, because of the importance of the stress mechanism for behavioural biology education this embedded practice has a key position in the storyline.

The second practice at vwo level starts with a thought experiment about students' own stress experiences, and students conclude that stressors could be mental, emotional, and physical. This LTA[5.2] (see chapter 8) links life-world practice experience to the embedded professional practice about exercise training, wherein physical stressors play a great role. The steering question how to prevent overtraining evokes the need to know how to measure the stress level, which legitimizes the change to the research of the overtraining syndrome. Another link is indicated by the question on the similarities between the overtraining syndrome and burnout.

2. Embedded practices were used to introduce specific (scientific) knowledge. Understanding the physiology of the stress mechanism requires knowledge that is acquired in other (scientific) practices. For example, although practice 2 differs at havo and vwo level, at both levels the physiological backgrounds of the stress mechanism requires a scientific practice. Because the concept CORTISOL is mainly used in scientific practices, it is unavoidable to introduce the molecular level of behaviour and the physiology of the stress mechanism in the use of embedded practices. Measuring cortisol is not a standard routine of for example, blood research. Cortisol can be measured in saliva, and that is mostly done in a medical setting. However, stress is part of behaviour, so studying stress is not the same as studying behavioural biology. Therefore, embedded practices seems to be required for learning and teaching the stress mechanism (see figure 15 and figure 21), which should lead to an understanding of the system of the hormonal processes of stress and behaviour.
At havo level research on weaning stress in young pigs is introduced after the introduction of the second practice, and finding an answer to the steering questions should result in an adequate understanding of the physiology of the stress mechanism. Therefore, some researchers at Wageningen Agricultural University explain on a video about their investigations of stress and behaviour with pigs, wherein they measure cortisol as a criterion for the stress level. They also tell about the relation between stress and the metabolism and growth of the pigs.
Recent research articles are also useful, for example about the research on the influence of (a lack of) behavioural imitation in human interactions to salivary cortisol levels (Kouzakova, Van Baaren, & Van Knippenberg, 2010).

3. As we argued above the stress mechanism has a key position in the strategy, and the embedded practice about the model of Selye should provide for coherence between the three perspectives on behaviour of Tinbergen.

Every change of practice should be accompanied by recontextualisation by students, because of the assumption that the meaning of a concept depends at least to some extend on the context in which the concept is used. However, because of the embedded character, the concepts used in embedded practices are part of the language of that educationally appropriated practice. Compare it with a newspaper, which is a collection of information from different practices, providing for a view on society. Therefore, we suppose that when embedded practices meet one or more of the above-mentioned purposes, recontextualising will not be necessary.

Summarising, we claim that an embedded practice

- can be elaborated preferably within one LTA and has to elicit a motive for a new steering question. When an embedded practice contributes to an uninterrupted storyline, recontextualising of the embedded practice is probably not required. On the other hand, inserting an LTA based on an embedded practice could increase educational complexity.
- is a precondition for acquiring specific (scientific) knowledge for an adequate execution of the LT-activities of the practice.
- can provide coherence in complex behavioural systems is by relating the three perspectives.

6.4 Description of interaction in the LT-strategy

Participation in a social practice supports the view that learning is the product of interaction between a person and his environment (design criterion 2). However, since a social practice is not the same as its educational derivative, as described in section 2.4, interaction in an educational practice can be classified in three types (Kirschner, 2006; Ruijters, 2006):

- learner – teacher
- learner – learning tools
- learner –learner

How will interaction encourage the learning process in the LT-strategy? Interaction is elaborated in the LT-activities undertaken by teacher and students. In this section, we subsequently describe the interaction between student and learning tool, between student and teacher, and between students mutually.

Interaction student – teacher

Although the learning materials allow a high degree of autonomy, interaction between teacher and student is required for supporting students' conceptual development. This interaction is programmed in the teacher's manual. Table 7 gives an example of the teacher's manual for the first lesson. Interaction between student and teacher consists mainly of an educational learning conversation (ELC), whereby the teacher has to ask the right questions to invite students to think about behaviour and to answer. Therefore, the structure of this conversation is written down in the manual.

Other parts of the interaction between student and teacher are reflection activities, where abstract concepts are elicited from the concrete practice. (In addition, there are short moments in the workbook where students are asked to write down a short summary or where summarizing questions are asked. These assignments are mostly inserted at the end of a paragraph on one of the three perspectives.)

The main reflection phases are situated at the end of each practice, and students reflect by designing concept maps. After having designed an individual concept map, the teacher, working with the students, makes a concept map. Figure 21 is an example of a concept map of the first practice, made by the researcher. This concept map shows that not only the concepts of behavioural biology (shaded concepts) are included, but also concepts that are necessary to make a continuing storyline and to carry out the activities of the practice. The stress mechanism (General Adaptation Syndrome) has a central position, because it is the main theme throughout the practices. In the first practice, attention is paid to the (healthy) reaction to acute stress, while in the second practice the attention moves to chronic stress.

Interaction student – learning tools

From the outline and description of the practices, a sequence of lessons is elaborated. This sequence is written down as a schedule at the beginning of the students' workbook. This learning plan is comparable with the lesson plan, and is completed with homework and remarks. The learning plan also describes the manner of assessment.

Learning activities and materials form a salient part of the interaction between student and subject. The learning materials consist of a workbook, a website with videos and software for the construction of concept maps. A workbook serves as a source for learning activities, both mental (thinking process), and physical (e.g. group activities). The workbook starts with a brief introduction of the learning goals (see section 5.3.5), and the focus lesson follows. Next students find the acquisition and extension practices. The test practice is put in a separate workbook[16]. Articles from the internet provide text sources for the workbook, although they were modified in language, length and level. In addition, the questions about the articles intend to stimulate the learning process and to connect previous knowledge with information from the articles. The learning materials on are supported by videos and the use of the computer. Nearly all videos are sourced from the internet, and after organizing, built in a website, so students can use them in the school library or at home. For the WebQuest 'Pork Plaza' (a design of a mega stable for pigs, practice 2a) the use of the internet is required.

Interaction student – student

Cooperation between students is an essential part of interaction. Ebbens & Ettekhoven (2005) mention two conditions for effective collaborative learning, namely positive mutual dependency and individual approachability. Students need each other to complete a task and all group members have their own responsibility for a part of the performance of the task. Group work (with four or more members) in the scenario is based on these conditions. In 'Pork Plaza' all group members have a different role, but it is the collective result what counts.

Further interaction appears in learning activities where discussion is well defined, e.g. work in pairs on a concept map. The final assignment, writing an article in the test practice, is also a task for pairs.

[16] The learning materials (in Dutch) can be found on http://www.vanmoolenbroek.nl/

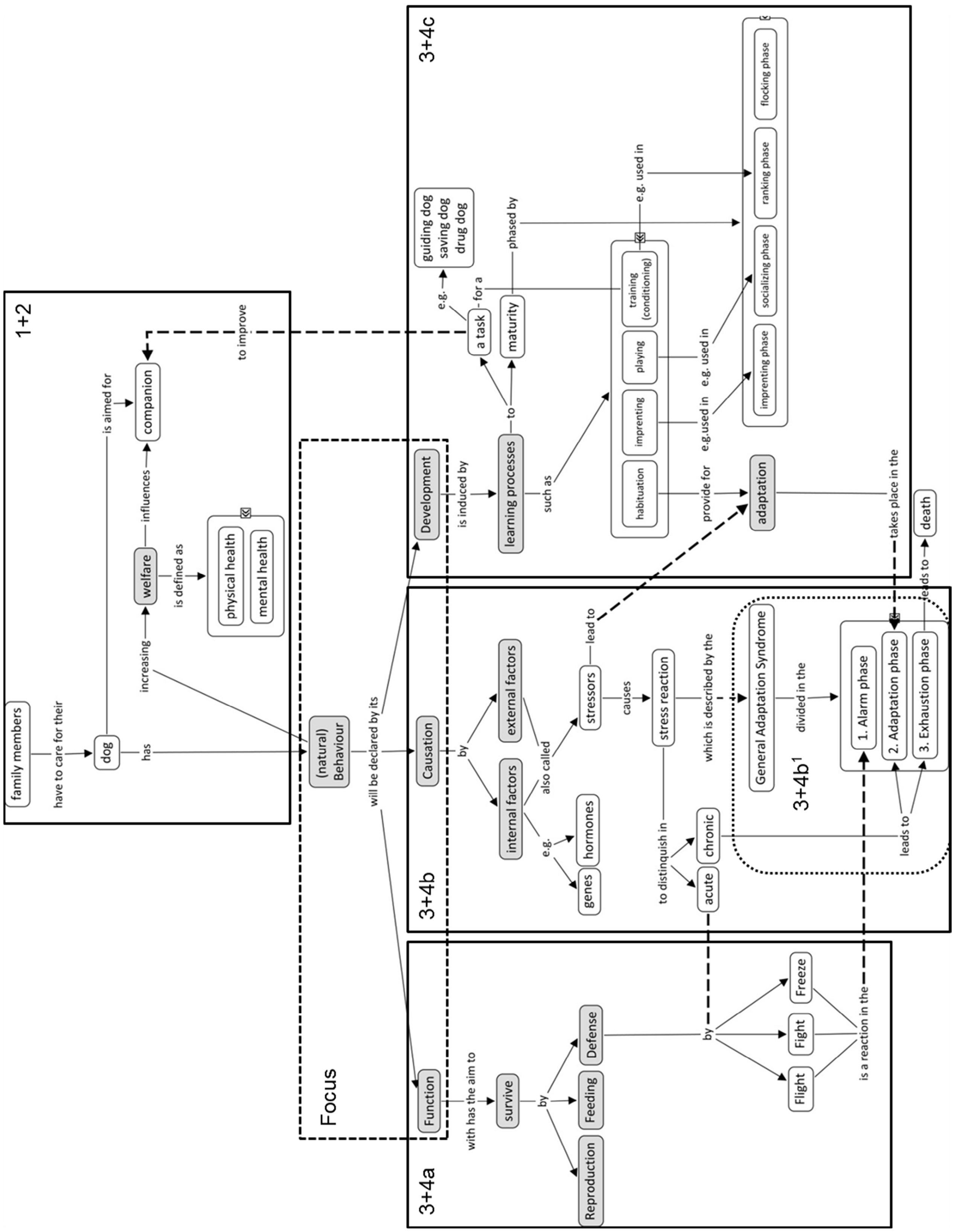

Figure 21. Concept map of the first practice. The frames and the numbers refer to the phases of the problem posing cycle of the practice (section 2.4.1). The frame with the dotted line contains the concepts that have to be acquired in the focus lesson (see section 6.2) and the box with the rounded corners stands for an embedded practice (see section 6.3.3). The dotted lines show the cross-links between the phases. The shaded concepts are the selected concepts of behavioural biology (see figure 11).

Table 7. Fragment of the teachers' manual.

<table>
<tr><td colspan="2"><h1>Lesson 1</h1></td><td>HAVO & VWO</td><td>March 2008</td></tr>
<tr><td colspan="2">Storyline:
The first lesson is aiming to take away students' matter of course of behaviour and lets them pay attention to the question why an animal is doing something.
Students will understand that behaviour is a biological concept and they learn to use three perspectives (function, causation and development) at the explanation of behaviour. These perspectives are elaborated in the next practices. At the end of the lesson students will understand which practices will be explored.</td><td>Goals:
Students are able to explain the difference between observing and explaining behaviour.
Students are able to convey that it is important to investigate behaviour to explain it.
Students are able to formulate the three questions of Tinbergen.</td><td>Utilities:
Video's:
01-hond en baas.wmv
02-asieldieren.wmv</td></tr>
<tr><td colspan="4">Central question: How can we explain behaviour? "Why does he do that?"</td></tr>
<tr><td colspan="4">Course: LTA[1.1-1.4]</td></tr>
<tr><td></td><td colspan="3">Distribute the workbooks</td></tr>
<tr><td>Introduction of dog behaviour</td><td colspan="3">• Introduction: "Many of you have a pet, and maybe even a dog. Here I have a video and I'm curious about your thoughts about it.
• Students observe the video: "Dog and Master"
• Set video on pause before the moment that the dog wants to lick its master.
• Let students do assignment 1 in the workbook (silence)</td></tr>
<tr><td>education learning conversation (ELC): difference between explaining and observing</td><td colspan="3">• Inventory the students' answers
• Let them identify the difference between observing and explaining, e.g. by comparing two answers.
• Important question to ask when students present an interpretation: How do you know that?
Be alert for statements that emerge in the next lessons, e.g. in the discussion about the question "how do you know that?" there could be an answer showing the influence of the environment on behaviour.</td></tr>
<tr><td>ELC: expectation</td><td colspan="3">• Let students do assignment 2.
• Ask: "What is going on with that dog?" and "What are we going to see the next moment?"; "Why do you think that?</td></tr>
<tr><td>Continue the observation of the video</td><td colspan="3">Continue video playing. (The lick is unexpected, so the question arises "Why…?" and behaviour is problematized).
Let students do assignment 3 in the workbook.</td></tr>
<tr><td>ELC: How could we explain the shown behaviour?</td><td colspan="3">• Inventory the answers
• "What is the right answer?" That is difficult to say!
"Our expectations were not correct. We are thinking as humans.
Conclusion: actually we have to 'ask the dog'.
Because this is impossible, we have to do some research. How do you research behaviour?"</td></tr>
<tr><td>Observation of the video for an explanation for dog behaviour</td><td colspan="3">1. Introduce: "let's take a look at the explanation of the dog licking"
2. Students watch video 02
3. "What is the meaning of licking?" (subservience)
4. "What is the opposite of subservience?" (dominance)
5. "Can a dog be both?"</td></tr>
<tr><td>Reading text</td><td colspan="3">• Ask: "Why is a dog subservient or dominant?"
• Introduce the reading text "Dominant or subservience" by asking students to search in the text after explanations for such behaviour. "Which explanations can be found of dominant behaviour?"</td></tr>
<tr><td>ELC: discussing the found explanations</td><td colspan="3">• "Which explanations did you find?" Write all answers on the blackboard.
Students' possible answers:
'It is in it'; dogs descend from wolves
Testosterone
Nurture (learned)</td></tr>
</table>

	To prevent conflicts *Etc.* • Ask: "Which explanations belong together?" Categorize the list. • Explain the three perspectives: Behaviour has a goal (function) Behaviour has a cause Behaviour is learned (development) In biology, this is the way to look at behaviour. To understand behaviour, you must know the meaning of behaviour.
Introduction practices	• Ask: "Three perspectives: focusing on which, through what and how? Do you know enough about behaviour when you get answers on these questions? When are you dealing with the function of behaviour and when with its causes?" • Indicate that these perspectives will be elaborated in three situations (contexts, practices), wherein behaviour plays a role: Carrying your pet Researching overtraining (VWO) Designing a welfare friendly stable (HAVO) Dealing with aggressive people In the first two practices, we acquire new knowledge and the third context is a test. • We start at home: caring your pet. (If there is enough time, an inventory can be made of the experiences students have with pets and why they have pets.). • Answer questions 6-8
Homework	**Answer questions through question 23**

6.5 Evoking motives

A characteristic of the problem posing approach is that at any point it should be clear to students what they have to do, when and why (Klaassen, 1995). From the domain-specific philosophy about learning and teaching (section 2.4), two criteria are derived. First, the problem posing approach generates the desired questions for students, and second, there must be a logically sequence of motives. We call this logical sequence of motives the ‘storyline', wherein the motives for participating in LT-activities are induced by the preceding LT-activities.

The structure of the problem posing cycle consists of six stages, divided in three main phases: questioning, learning activity[17] and reflection. We have adopted the following division in writing the storyline as a sequence of questions (or problems), learning activities and reflection or answers (see figure 4). The short time that some problem posing cycles take does not always permit a division in six stages.

The LT-strategy is elaborated in nested problem posing cycles. First is the level of the whole strategy (figure 19), which can be seen as one problem posing cycle. In contrast with previous design research, e.g. Westra (2008), our strategy starts with a focus lesson, which is the questioning phase. This focus lesson results in the central steering question, and contributes to the development of the three perspectives, according to Tinbergen. The first and second practices (acquisition and extension, see figure 19) can be seen as stage 3 and 4, while the test practice is the reflection phase (stage 5 and 6) of the problem posing cycle.

The second level is at the level of the practice, led by a steering question. After evoking the steering question (questioning phase), the three perspectives of Tinbergen are elaborated (activity phase), while

[17] Although the phases questioning and reflection are also (part of) learning activities, here, this phase is called learning activity in order to distinguish it from the activity of an authentic practice.

the reflection lesson at the end of the practice serves as the reflection or answering phases of the problem posing approach.
The third level is the level of learning and teaching activities (LTAs), as sequenced within a practice (see figure 4).
As an example, figure 22 presents the problem posing cycle of the first lesson (Focus). The structure is adapted from earlier Ph.D. studies at Utrecht University (Klaassen, 1995; Vollebregt, 1998; Kortland, 2001; Knippels, 2002). On the left side, students' knowledge is indicated and on the right side, the specific motives that have to be evoked when learning activities are executed. The numbers in the text refer to the phases of the problem posing cycle. Following Westra (2008), motives are evoked by the teacher in our LT-strategy by asking the right question in the zone of proximal development of students. These questions are generally mostly prescribed in the teacher's manual.
A non-interrupted storyline supposes a sequence of motives, while the three questions of Tinbergen are not sequential. The perspectives of Tinbergen can be better understood as three parallel lines. These three topics appear in the used practices and the challenge is to design these three perspectives in one storyline. Figure 21 visualizes stages 1-4 of the problem posing cycle in the concept map of the first practice. In a quest for clarity not all concepts and relations are indicated. And although there is a hierarchical order in the concepts, the concepts were not taught hierarchically, because the storyline takes precedence. To construct a non-interrupted storyline, the relations with the dotted lines are important, because they provide connections between two perspectives.

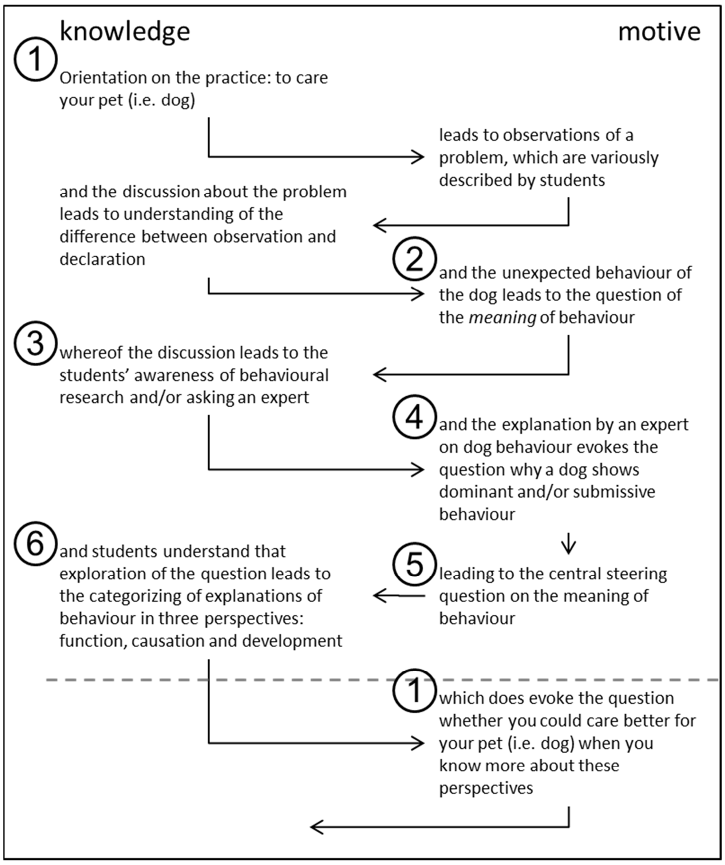

Figure 22. The problem posing cycle of the focus lesson. The numbers refer to the phases of the problem posing approach (section 2.4.1). The dotted line indicates the transition to the first practice.

7 Research instruments

As described in chapter 3, the LT-strategy is empirically tested in educational practice. In this chapter we describe the research instruments. First, we give an overview of the classroom setting, including an account for the selection of case studies. Second, we justify the selection of the methods for data collection and analysis.

7.1 Classroom setting

To investigate the efficiency of the LT-strategy two research cycles including an evaluation in classroom are set up. Table 8 shows the characteristics of the schools involved in these case studies.

Table 8. Characteristics and details of the schools involved in the case studies of the two cycles.

General school indicator	First research cycle		Second research cycle		
Name – place (code)	De Passie – Utrecht (1a)	Driestar College – Gouda (1b)	Jac. P. Thijsse College – Castricum (2a)	Driestar College – Gouda (2b)	Krimpenerwaard College - Krimpen aan de IJssel (2c)
Denomination	Evangelical	Orthodox Protestant	State	Orthodox Protestant	Particular
Number of students	730	3110	2044	3100	1109
Average grade national exam 2008 [18]	H: 6.4 V: 6.3	H: 6.5 V: 6.8	H: 6.3 V: 6.3	H: 6.5	V: 6.9
Number of classes and students participating	2 classes H: 23 V: 16	2 classes H: 24 V: 23	2 classes H: 25 V: 23	1 class H: 27	1 class V: 20
Grade and level[19]	4H 5V	4H 5V	4H 4V	4H	4V
Age of students	H: 15-16 years V: 16-17 years	H: 15-16 years V: 16-17 years	15-16 years	15-16 years	15-16 years
Number of biology lessons per week	H: 3 V: 4	H: 2 V: 3	H+V: 3	3	2
Duration of a biology lesson (minutes)	45	50	50	50	50

[18] Average of the subjects Math, Physics, Chemistry and Biology. Nationwide H: 6.3-6.6 and V: 6.1-6.6. Source: http://www.onderwijsinspectie.nl/

[19] H = HAVO, upper general secondary education; V = VWO: pre-university education

General school indicator	First research cycle		Second research cycle		
Number of teachers involved	2	1	2	1	1
Number of lessons behavioural biology in the case-study	11	10	H: 12 V: 14	12	12
Time period case-study	January-February 2007	February-April 2007	April-May 2008	May-June 2008	September-October 2008

The selection of teachers for participation in the case studies was based on pragmatic considerations. For the first research cycle we sought in our own network, and we asked a colleague biology teacher from our own school (Driestar College, until June 2007) to cooperate. He taught both at the havo and vwo classes. A second case study of the first research cycle was found at the Passie. A colleague taught the vwo classes and her colleague who also wanted to cooperate, taught at havo classes.
For the second research cycle, we selected three schools. The first school, the Jac. P. Thijsse College was a "biology development school" (BDS), which means that biology teachers at that school tested an experimental examination program (Boersma, et al., 2005). This also implied that the involved teachers and students at the Jac. P. Thijsse College were familiar with the desired biology education innovations, and also with the concept-context approach. Both a havo and a vwo class were observed.
For a second havo-4 class, once again one of the biology teachers of Driestar College wanted to cooperate and finally, the other vwo-4 class was found at the Krimpenerwaard College. The biology teacher of that school was familiar with the concept-context approach and the problem posing approach because of his own Ph.D. research at Utrecht University. All teachers were interested in teaching according to the concept-context and the problem posing approach and they were in able to adapt their usual teaching practice.
Before the start of each case study, teachers were prepared by introducing the learning and teaching approach. In addition, we developed a teacher's manual providing information about the use of the learning materials (e.g. workbook). In the first research cycle we allowed the teachers substantial freedom in planning their lessons. In the second research cycle, wiser through these experiences of the first, we decided to guide the teachers more in detail by discussing every step in the scenario. We also adjusted the teacher's manual by describing the process in every lesson systematically, including the students' answers that would be expected.

To manage time, all parts of the research cycles were carried out at varying, but almost always contiguous periods. In the first cycle, the havo-4 class at Driestar College (1b) had two lessons weekly, and a holiday and a lab test about another topic interrupted the research period. In addition, at both schools we had to manage with the available lesson time and the need for a written test. With these experiences, we urgently requested in the second cycle for at least 12 lessons. In the second research cycle, each case study was non-interrupted. The individual case studies were interrupted by the summer holiday. The research period depended of the place on behaviour in the curriculum. In one case (Krimpenerwaard College), the teacher displaced the topic forward in the school year.

Selection of classes was based on their regular scheduling in combination with the availability of the researcher. One exception was the vwo-5 class at the Driestar College, where the subject behaviour was scheduled at the beginning of the year. For practical reasons in the second research cycle, vwo-4 classes were selected instead of vwo-5 classes as in the first cycle.
In the Dutch educational system students in class 4 (15-16 years) in havo and vwo level have chosen one of four profiles. Two of these profiles are science oriented and the other two have a cultural and economic orientation. Students have a free choice for one subject in each profile, so also students with an economic/culture profile can select Biology. Some students in havo-4 chose Biology for pragmatic reasons; they thought Biology would be an easy subject.

Before the start of a case study, the researcher was introduced to the students in a letter that contained a short explanation about the research and an announcement regarding video and audio recordings. At the start of the lessons, we introduced ourselves as a fellow teacher, also working as a Ph.D. researcher at Utrecht University. We explained the main goal of the research and stressed the importance of answering of the questions in the learning materials honestly, adding that we appreciated all kinds of feedback. It was also explained that all data and worksheets were only for research purposes and would be handled confidentially. Students were told that the series of lessons about behaviour were a substitute for the corresponding chapter in the biology textbook. After distribution of the workbook, the teacher explained the study guide that was included in the workbook.
During the pilot there was interaction between the students and the researcher in all classes, from the normal greetings to a conversation about the role of the audio and video recordings. In the first version of the design the researcher had limited himself to observation of the lessons. In the second version the researcher sometimes participated in the teaching process, when students were working with the worksheets or during group work. This approach gave the researcher the opportunity to find out how activities were interpreted. Also, short interviews with students were convened when remarkable study behaviour was observed, e.g. working ahead in the workbook.

7.2 Data sources and analysis

The LT-strategy is elaborated in a scenario. A scenario prescribes in detail the storyline of the strategy with all LT-activities of students and teachers and their intended learning outcomes. The scenario predicts and theoretically justifies the expected learning and teaching processes, can be considered as a hypothetically learning and teaching trajectory (Klaassen, 1995), and is thereby empirically testable (Lijnse, 2002; Lijnse & Klaassen, 2004).
From the scenario learning materials were developed in a reciprocal process of writing the scenario and designing the LT-activities and materials. The scenario is also the basis for the teacher's manual. Finally, the scenario is used as an observation instrument during testing the lessons in the classroom. Table 9 shows as an example a part of the scenario at the beginning of the second practice at vwo level.

Table 9. Part of the scenario: second part of the 5th lesson about the second practice 'researching overtraining' at vwo level.

Content	Motive	Teacher's Activities	Student's activities	Learning objective	Monitoring
In the practice 'researching overtraining of horses' the emphasis is on the mechanism of chronic stress. What happens when stressors continue? Students understand the physical reaction by thinking about a stressful situation. With chronic stress the body recovers insufficiently and a human or animal is risking on burnout or overtraining. When do you know what is the limit? (...)	What happens when humans suffer from stress?	Do the thought experiment about a stressful situation with students. Discuss the thoughts, feelings and physical reaction that students call. e.g. ask what, how and why happens. Let students think what happens when stress is too much or too long.	Students think about a stressful situation and express their thoughts, feelings and physical reactions with stress. They name panic, clammy hands, shaking knees and increase of your heart beats. Thinking is not clear. Students say that the heart beats faster, because the need of pumping more blood through the muscles. They name the flight/fight reaction. Students conclude that the reaction on stressors is both a physical and mental reaction. They realize that stress is necessary for performance, but that too much stress is harmful for the welfare of human and animal.	Students are able to describe their own (mental and physical) reaction to a stressful situation.	**What** Do students understand that adaptation to stressors is meant to survive and that taking insufficient rest results in overtraining / burnout and therefore harms welfare? **Why** Students have learned in previous practice that the function of behaviour is survival and that the stress reaction is a manner of defence (fight/flight/freez e) **How** Analysis of the collected data shows the insight of students e.g. by naming the fight/flight reaction. They know that the welfare is threatened through overwhelmingly stress.

The aim of this study is to search for an adequate LT-strategy for behavioural biology. Therefore, the analysis of research data has to focus on the students' understanding of behavioural biology concepts, and should consist of a comparison of the scenario with the gathered data, evaluating if the scenario is executed as intended. In addition, the empirical data are used to determine whether the LT-strategy is adequate or not. When the execution differs from the intended strategy, it must be determined what these differences indicate for revising the scenario or even the LT-strategy. In all case studies, a diversity of data was collected. In this section, we present a framework and an underpinning for data selection and a description of the data analysis. Therefore, data selection and analysis should be based on the following two questions:

1. Is the scenario executed as intended?
2. Are the desired results achieved?

Both questions will be answered at the level of the LTA. From the possible answers to these questions, a matrix can be made. Table 10 indicates the four options providing a framework for data selection and analysis of the case studies.

Table 10. Framework for data selection and the analysis of the case studies.

	Intended scenario executed	Intended scenario not executed
Desired results achieved	A. The LT-strategy is adequate.	B. What are the causes for the deviations from the scenario?
Desired results not achieved	C. How should the scenario, and possible the LT-strategy, be adapted?	D. Refocus on the LT-strategy: is a redesign necessary?

The LT-strategy is tested in two research cycles, each with four case studies. The first research cycle had an explorative nature, indicating for the main bottlenecks in the design. Therefore, the question if the execution of the scenario is as intended will be answered in chapter 8, where the main findings of the first research cycle will be presented. These findings resulted in a refocus on the LT-strategy (option D), and a few adaptations were elaborated. In addition, chapter 8 provides for a global overview of the execution of the second research cycle as a base for the empirical evaluation of the second version of the LT-strategy. A detailed empirical evaluation of the final LT-strategy on the level of an LTA is described in chapter 9. Table 11 shows an overview of the data sources used for the empirical evaluation of the LT-strategy.

Table 11. Overview of the data sources collected in the case studies and used for empirical evaluation of the LT-strategy.

Data source	Collected	Aimed	Used
Observations by the researcher	In all lessons written notes were made. Unexpected situations and remarkable statements of students and teacher were noted that (in)validated the expected activities in the scenario	First and quick comparison of the intended and executed scenario	Used for the selection of relevant audio fragments, and a general comparison of the executed scenario with the intended scenario
Audio recording of classes and groups	In all lessons audio recorders and video cameras were placed in the classroom. In the case of group work, recorders were placed at the students' table	Actual and textual reproduction of the course of the lesson series	Relevant audio fragments are transcribed verbatim and translated in English
Workbook	In all lessons the lesson materials consisted of a students' workbook.	Indicate for students' thoughts and reasoning	Students' answers to specific questions are used
List of concepts*	Assignments in the workbook in the second research cycle	Indicate for students´ thoughts about the concepts of the practice	All listed concepts are analysed. The analysis method is described separately in this section
Concept map*	Assignment in the workbook in the second research cycle, all practices	Indicate for students' conceptual development, and the recontextualisation process	The technical and domain-specific quality of the concept maps is determined. The analysis method is described separately in this section
Written test	In the first research cycle, third practice	Indicates for students' understanding of the behavioural biology concepts	Used to explore the effectiveness of the first version of the LT-strategy
Essay	In the second research cycle, third practice	Indicates for students' conceptual development, and the recontextualisation process.	Used for the investigation of the relationship between concept map construction and essay writing. The analysis method is described separately in this section
Evaluation form	After the execution of a case study, an evaluation	In the first research cycle: indicates for students'	Statements of students are used to evaluate the lesson

Data source	Collected	Aimed	Used
	form was filled in by students, containing questions about the motivation of students and valuation of the lesson series	evaluation of the lesson series. In the second research cycle: also an indication for students' understanding of the learning objectives	series and materials in the first research cycle. The forms are also used to indicate for the adaption of the strategy. In the second research cycle, evaluation forms are used to elaborate students' self-evaluation of the learning objectives
Reflections with teachers	After each lesson of the second cycle. Finally, an evaluation interview was taken with all teachers after execution of the scenario.	Indicate for teachers' understanding of the scenario.	Teachers' statements are used to illustrate what is observed in the lessons
Observation of a pretested focus lesson with a small group of students	Between first and second research cycle	Pretesting the focus lesson for the second version of the LT-strategy	Used to pre-test the focus lesson in the second version of the scenario. Observations are used to fine-tune the focus lesson and the teachers' manual

* Lists of concepts and concept maps are both part of the workbook. Because the lists of concepts are important data sources we discuss them apart from the workbook.

Used data fragments are supplied with a code: [case study, data source, what or who]. For example, the code [1b_v, evaluation, Eline] means:

1b_v	first case study Driestar College vwo level (see table 8)
Evaluation	written self-evaluation after the lessons series (see Table 11)
Eline	students' name

Analysis in the first research cycle

Because of the explorative nature of the first research cycle, the empirical analysis of the data is reported only briefly. Mainly three data sources were used. Based on the observation of the researcher, the executed scenario is compared with the intended scenario. The answers on the written test were analysed, and students' evaluations of the lesson series are elaborated for indications on how to improve the LT-strategy.

Observations by the researcher

In the scenario the LTAs were distributed over 12 lessons. In section 8.1, the executed distribution of the LTA will be compared with the intended scenario.

Written test

At the end of the lesson series in the case studies of the first research cycle, a written test was conducted, aiming to elaborate students' understanding of the behavioural biology concepts in an unfamiliar practice. Because of time pressure at the schools where the case studies were conducted, this practice could not be explored adequately. The written test consisted of nine tasks that were introduced with a short article about the inadequate dealing of police officers with aggressive people. Subsequently, each task was introduced by a short text, which directed the attention of students to one of the perspectives of Tinbergen. One or more questions were asked about the topic, as illustrated by the following example:

> "Aggressive behaviour in young children is closely linked to the child itself (its character, age, empathy), stress and problems within the family (divorce, quarrels), its lack of skills (dealing with fear, anger), a lack of clear rules, low self-esteem, the stress and violence in society (e.g. traffic, tv), negative sample behaviour (e.g. in the media).
>
> Consequences?
>
> Children showing violent behaviour already at a young age often showed problem behaviour in later life. If they do not learn to deal with their aggression, they stay in conflict with themselves and their environment."
>
> **2a. Name the causes mentioned in the article of some internal and external factors. (2 points)**
>
> **2b. Indicate two fragments from the article where the development of behaviour is mentioned. (2 points)**
>
> [1, written test, question 2]

The test ended with a task whereby students had to argue about a knowledge base about aggression for police officers. They had to use the prescribed concepts of the behavioural biology: development (LEARNING), function (SURVIVAL, DEFENCE, FEEDING, and REPRODUCTION), and causes (INTERNAL AND EXTERNAL STIMULI).

Students' answers (n=869) were listed for each task and compared with the correct answers. Furthermore, the answers are sorted by behavioural biology concepts (see table 6) in order to get insight into students' understanding of the behavioural biology concepts. The analysis of the written test is presented in section 9.2.

Students' evaluation

In the students' evaluation of the lesson series in the first scenario, students were asked for their experiences with the different parts of the lesson series, for example how they evaluate the LTAs about building a welfare friendly pig stable. Two open questions asked about the students' ideas about what could be improved and about what they liked in the lesson series. The students' evaluation is used in particular in section 8.1.

Analysis in the second research cycle

The second research cycle delivered new data for the analysis of students' conceptual development. Because of the large amount of data, a selection had to be made for analysis. This research cycle is aiming to provide an empirical underpinning of the effectiveness of the LT-strategy for behavioural biology. According to the distinction of Ruijters (2006) and in line with our view on learning and teaching (chapter 2), we evaluated the students' conceptual development by focussing on its three components: *interaction*, *reflection*, and *construction*. *Interaction* between a learner and its environment is a requirement for learning. *Reflection*, the third step in the problem posing approach, should evoke awareness of the behavioural biology concepts, and therefore, evaluating the reflection phases of the LT-strategy indicates how students developed the behavioural biology concepts. Finally, *construction* connects relevant knowledge with prior knowledge, and evaluation of the construction process provides insight both in students' conceptual development and the recontextualisation process. Table 12 presents an overview of the three components, and indicates which parts of the LT-strategy were used, and the place in chapter 9 where the results of the analysis are presented. Note that concept maps are used in two components of the conceptual development.

Table 12. Overview of the components for the evaluation of students' conceptual development.

Components of conceptual development	LT-strategy components used for evaluating Students' conceptual development	Described in (Sub) section
Interaction	• Class discussions (audio recordings) • Learning material (workbook)	9.4.1
Reflection	• Reflection periods (audio recordings) • List of concepts & concept maps practices 1 and 2	9.4.2 9.4.3
Construction	• Embedded practices • Concept maps practice 3 • Essays	9.5.1 9.5.2 9.5.3

Observation of the researcher and audio recordings

In the scenario the LTAs were distributed over 12 lessons. In section 8.2 the executed distribution of the LTAs is compared with the intended scenario. Furthermore, the comparison of the scenario is expanded with the observations and relevant fragments of the audio taped lessons that were transcribed verbatim. Significant audio fragments are for example class discussions, particularly during the reflection phases.

Workbook
Students’ answers to the questions in the workbook indicate the interaction with the learning materials, and for its effectiveness. Relevant answers were listed to compare and categorize answers. Important questions deal with (dog) stress or the stress mechanism in the second vwo practice. For example, students had to write a summary of the article about dog stress in order to show their understanding of the concept CAUSATION. From this article, a tag cloud is included in the workbook. Figure 23 shows the tag cloud of the translated article about dog stress. Students had to summarize the article by means of the words of the tag cloud.

Figure 23. Tag cloud of the translated article about dog stress. The numbers indicate how many times a word appears in the text. (Made with tagcrowd.com)

Students’ self-evaluation of the learning objectives
After finishing the lesson series, the students assessed in a self-evaluation the extent to which they recognized the learning objectives formulated in the teachers' manual for each lesson. For that purpose, the learning objectives were adapted to statements. For example, one of the learning objectives of the focus lesson is that students are able to formulate the three perspectives of Tinbergen. In the self-evaluation this statement appears: *“I am able to formulate the three perspectives of Tinbergen.”* Students could choose between ‘yes’, ‘a little’, or ‘no’. In addition, a few open questions regarding the students’ experiences with the lesson series complete the evaluation. The outcomes of the students’ self-evaluations are used in particular in the sections 9.3 and 9.4.

List of concepts
At the end of each practice students compiled a list of concepts that they marked as important for that practice. They also defined the concepts, so these lists are important sources for the analysis of their conceptual development. The analysis encompasses both which and how frequently concepts are noted, and a comparison with the list of behavioural biology concepts that we have defined as the minimum for learning behavioural biology (see table 6). Where descriptions were not clear, we checked the intended and executed scenario in order to seek possible causes and improvements.
We distinguished the following three categories of concepts:

- *bb*: behavioural biology concepts. In table 6, we defined these concepts as the minimum set of concepts for behavioural biology.

- *sm*: concepts used in describing the stress mechanism. This mechanism is an important part of the extended concept map (figure 15) for learning and teaching behavioural biology. Actually, these concepts are part of the causation of behaviour.
- *c*: Context-related concepts which students noted in the lists of concepts after exploring the practice. In this category, concepts such as dominant behaviour, submissive behaviour, overtraining, aggression, and socialization are included.

All concepts noted in the lists were categorized in these three categories. In addition, from the category 'behavioural biology concepts' the relative distribution over the three perspectives is determined. The outcome of this analysis is presented in section 9.4.

Concept maps

Concept maps were analysed in two different ways:

1. The analysis of the technical quality in order to determine whether the concept maps were constructed as intended.

2. The analysis of the domain-specific quality in order to determine the students' conceptual development.

<u>Technical quality of concept maps</u>

Students constructed a concept map in the reflection lesson. A concept map would be constructed to answer the central steering question, 'how could we explain behaviour?' Students were instructed in the assignment how to design a concept map in the following five steps[20]:

1. Identify the relevant concepts,
2. Order the concepts from abstract to concrete,
3. Group concepts that are related to each other,
4. Arrange the (group of) concepts on paper (or digitally),
5. Connect the concepts where appropriate and add a linking phrase to every link.

The students' concept maps show big differences. Connecting concepts by linking phrases to construct a proposition is an important characteristic of a concept map, and the absence of the linking phrases in the students' concept maps is remarkable, as is illustrated by the following two examples of concept maps (figure 24).

[20] This instruction is taken from sources from the internet, for example http://olc.spsd.sk.ca/de/pd/instr/strats/conceptmap/index.html (Retrieved February 2012)

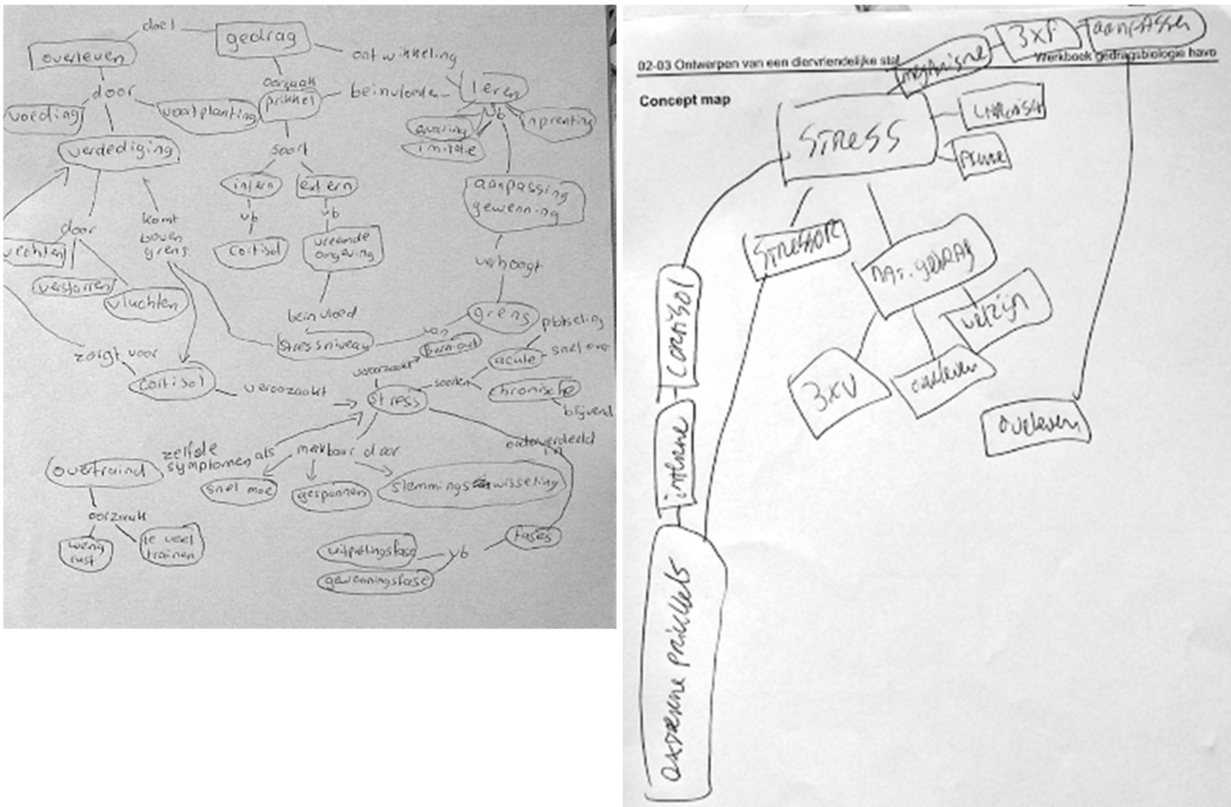

Figure 24. Two examples of students' concept maps, showing big differences in number of concepts, linking phrases, and design. Left: [2a_v, P2, Jan]; right: [2a_h, P2, Tom].

Therefore, it is indicated that the technical quality of the two concept maps is quite different. How could we define the technical quality of a concept map? Various methods of analysis of concept maps have been described by a number of researchers (CfT, 2007), whereby the scoring model of Novak & Gowin (1984) is commonly adapted. This model applies the following four criteria:

1. Propositions: each valid proposition scores 1point;
2. Hierarchy: each valid level of hierarchy scores 5 points;
3. Cross links: each valid cross links scores 10 points. (If the cross link is valid but is not showing a synthesis between sets of related concepts and propositions it only scores 2 points);
4. Examples. Examples score 1 point.

To develop an instrument for analysing with the scoring model of Novak & Gowin (1984) we scored three concept maps that were meeting the criteria for an adequate concept map. Figure 25 shows two examples of the concept maps used for the development of the scoring model.

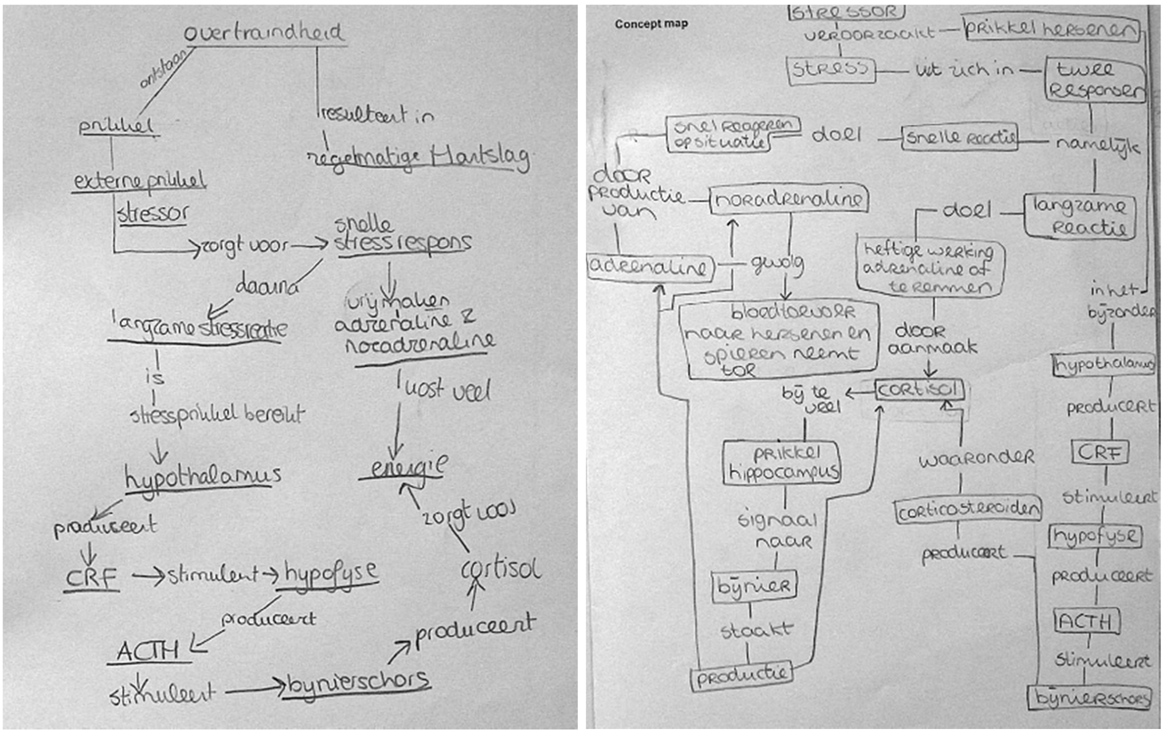

Figure 25. Examples of students' concept maps that were scored for developing the instrument for analysis of concept maps. (left: [2a_v, P2, Stephanie]; right: [2a_v, P1, Tessa])

From this exercise and a further analysis of the literature, we concluded that that the scoring model of Novak & Gowin (1984) did not satisfy for the following reasons.

1. Propositions. Many concept maps did not include valid linking phrases, and the number of propositions varied. Kharatmal & Nagarjuni (2006) indicate for the difference in experience between a novice and an expert, finding that an expert is able to make a smaller concept map, because an expert passes over several thinking steps. Therefore, a higher score of a concept map according to the above-mentioned score model is not necessarily better than a lower score. In our research, students must be considered as novices.
2. Hierarchy: many concept maps showed no hierarchy. Nevertheless, Åhlberg (2004) argues that there are reasons why good concept maps may not be always hierarchical: the world is a system with the characteristic of a web.
3. Cross links: when no hierarchy is indicated, cross links are difficult to determine. Furthermore, although cross links indicate for understanding when relating to other parts of behavioural biology, they probably will be indicated by experts and not by novices such as students. Therefore, the criterion of cross links is left out of the analysis instrument.
4. ‘Example’ is a type of a relationship between concepts. As a refining of the score model, Kharatmal & Nagarjuni (2006) determined several relation types indicated in the propositions, such as causality, part-whole, functional, and examples.

In sum, in the analysis model of Novak & Gowin the technical and domain-specific quality are not distinguished. Therefore, we had to define another scoring model for the technical quality of the concept maps.

When is a concept map technically satisfying? The technical quality of concept maps on behavioural biology it satisfying when linking phrases are included. We do not formulate the use of arrows in the concept maps as a criterion, because it was not included in the assignment. Nevertheless, the use of arrows could provide for clarity, in particular when no hierarchy in their concept maps is used.

Domain-specific quality of concept maps

The analysis of the domain-specific quality of students' concept maps (n=112) is elaborated both on the level of the concept map and on the level of the propositions. All propositions were considered, both the propositions with and without a linking phrase.

Propositions

To investigate the domain-specific quality of the students' propositions we developed an analysis procedure, consisting of the following steps:

1. From the basic concept map (figure 15), a list of propositions is derived (see table 21). These propositions serve as a reference to the students' propositions. Because of the diversity[21] of the students' propositions it appears that classification of the propositions by classifying concepts was a better method than classification with the list of propositions. A classifying concept is defined as the concept that is typical for the proposition. For example, the propositions *'the aim is to survive'*, and '*the aim is an explanation for behaviour'* are both classified under the concept FUNCTION. We added five classifying concepts, in table 21 indicated with the numbers 20-24. The concept NATURAL BEHAVIOUR is one of the behavioural biology concepts. The physiology of the stress mechanism is part of the lesson series, and obviously, there are propositions resulting from the practices.
2. All propositions from students' concept maps of the first and second practice were listed, including propositions from the technically invalid concept maps.
3. All propositions were classified by the classifying concepts. We classified the propositions by taking the concept first listed. When a proposition starts with a concept that is not listed, the second concept in the proposition is taken. For example, in the proposition *'space – stress'* the concept SPACE is not used in the lessons. It might be classified as 'environment', but that it is unknown if that was intended. So, the proposition is classified by the concept STRESS.
4. After having 10 concept maps analysed independently by two raters, all differences were discussed until agreement was reached. Every proposition is counted, even in the case of two similar propositions.
5. After classification, the propositions are categorized for correctness:

Category 1	Do the concepts have the correct order, according to the basic proposition? For example, in the proposition '*Behaviour is caused by stress'* the concepts BEHAVIOUR and STRESS are in the correct order, and a linking phrase is used.
Category 2	Are the two concepts correctly linked? When a linking phrase is not included, in a proposition several correctly linking phrases could be applied. For example, the function of behaviour is to survive (classifying concept 6), and FEEDING,

[21] A few propositions appear frequently in students' concept maps. However, most propositions differ from the others, in particular in the linking phrase. For example, the proposition *'bad welfare influences natural behaviour'* is essentially the same as *'bad welfare – natural behaviour'*. However, with the absence of a linking phrase in the last statement, these two statements are noted as two different statements. Nevertheless, both are classified by the concept WELFARE.

REPRODUCTION, and DEFENCE (in Dutch, the three V's) are behaviour systems that contribute to SURVIVAL (classifying concept 7). So, the statement 'the three V's – aim' is classified under proposition 7, with the concepts correctly linked to each other, because one could also say 'the three V's contribute to the aim (of behaviour)'.

Category 3 The proposition is incorrect. For example the proposition *'stressor through internal and external stimuli'* is incorrect, because a STRESSOR is a stimulus. Also the proposition *'hormone production provides for a stress response'* is incorrect because the stress reaction includes hormone production.

6. For each classifying concept, the relative distribution of the propositions is determined:

$$\frac{\text{Number of propositions per classifying concept}}{\text{Total number of concepts of all concept maps}}$$

This percentage shows to what extent a basic proposition is indicated.

7. Per classifying concept, the percentage of correct propositions (both category 1 and 2) is determined. This percentage could serve as a measure for the students' understanding of the basic proposition.
8. In order to understand to what extent a proposition appears in the concept maps, the ratio

$$\frac{\text{Number of correct propositions (category 1 and 2)}}{\text{Total number of concepts maps (112)}}$$

was calculated. Because of the fact that a classifying concept can embrace different propositions in a concept map, it is possible that the ratio between the number of correct propositions/number of concept maps is above 1.0.

Concept map

1. Per concept map, the ratio

$$\frac{\text{Number of the propositions}}{\text{Number of classified concepts (24)}}$$

was calculated. This ratio is a measure for the domain-specific quality of the concept map. A high ratio means that a student was able to relate the correct concepts. The ratios are summarized in ranges and the relative distribution of the propositions over the three categories (step 5) is calculated. With these percentages the question could be answered if students' highly rated concept maps have a higher domain-specific quality than the lower rated concept maps.

2. In addition, an indication for the domain-specific quality of a concept map could also be obtained by indicating the types of relationships between concepts. It is arguable that students who have a broad understanding of the topic use more different types of relationship. We analysed the relation types in the technically valid concept maps, distinguishing four categories:
   a. Causal, indicated by words as: caused, results, cares, influences
   b. Functional, indicated with: aims, produces, makes,
   c. Part/Whole, indicated with: divided, (such as), a form of

d. Example, indicated with: e.g., such as

The results of the analysis of the concept maps are presented in section 9.4.3. The results of the analysis of the domain-specific quality of all concept maps are shown in table 21. The results of the analysis of the domain-specific quality of the concept maps are shown in table 22.

<u>Concept maps of the third practice</u>

Students also constructed concept maps in the third practice. These concept maps are used in a preparation for essay writing. In section 9.5.2 we present the results of an analysis of the relationships between a selection of concept maps of the third practice and the corresponding essays. Considering the results of the analysis of the concept maps in the first and second practice, we reviewed the domain-specific quality of the concept maps by calculating the ratio

$$\frac{\text{Number of used behavioural biology concepts}}{\text{Number of all concepts of the concept map}}$$

In addition, the number of used perspectives in a concept map is noted by counting the actually noted concepts CAUSATION, DEVELOPMENT, and FUNCTION.

Essay

All essays were reviewed on statements about the three perspectives on behaviour, as is demonstrated in the example shown in table 13.

Table 13. Example of the classification of statements of a students' essay.

Essay	[2a_h, essay, Max]
General	Prevent riots by reducing peer pressure.
Problem	Each person is aggressive. "Aggression is the ability of people to defend themselves when attacked, in order to launch attacks themselves and to collect food"
Causes	Stress (caused by stress hormones), frustration, tension, and group pressure.
Function	Each person is aggressive. "Aggression is the ability of people to defend themselves when attacked, in order to launch attacks themselves and to collect food." "Securing the position within the group applies to riots." "By means of expressing aggression, a group can radiate power."
Development	"Aggression is in the natural character of a human being."
Solutions	"Aggression provokes aggression (...): show respect and do not discuss" "To stop a riot, violence is necessary." "Reducing peer pressure by many travel possibilities (and timed), enough body searchers (no waiting lines). For a remaining small group: separation of rioters and other stadium supporters in the stadium. " [Especially practical issues, insight into peer pressure, comment JvM]

The results of the analysis of the essays will be presented in subsection 9.5.3.

Knowledge is of no value unless you put it into practice.
Heber J. Grant

8 Outline of the intended and executed scenario

This chapter connects the LT-strategy as described in chapter 6 with its empirical elaboration in chapter 9. We focus on the question whether the scenario is executed as intended, providing a global overview of the execution. In chapter 3 we indicated that the interplay between educational theory and educational practice makes educational research difficult. Therefore, the first design of the LT-strategy had an explorative nature, expecting that it would show the main bottlenecks in the design. In this chapter we report on the main findings in the first research cycle (section 8.1). These findings resulted in an adaption of the scenario and the design. Subsequently, we describe the outline of the intended and executed scenario in the second research cycle, and we look for indications for the adaptation of the scenario after execution in the second research cycle (8.2).

8.1 The first research cycle

In the first research cycle, we selected the life-world practice of caring for pets, and the professional practice of designing a welfare friendly stable for pigs. The third practice in the scenario dealt with the aggressive behaviour of humans. All practices are authentic and recognisable for students. The content of the first two practices was described in section 6.2.3. Because of a lack of time, the third practice was executed as a written test.

According to the basic concept map (figure 13) the learning material is built with the concept WELFARE as a starting point. After that, the concepts NATURAL BEHAVIOUR (function), STRESS (causation), and ADAPTATION and LEARNING (development) follow. In the second practice further elaboration of the concept STRESS is released by introducing the work of the stress hormone cortisol in a feedback loop of the stress mechanism.

The first lesson of the scenario is designed to evoke the central steering question “Why do they do that?” Students observe videos showing behaviour of a diversity of animals, such as mice, Komodo dragons, snakes, and cuttlefishes. All videos show unexpected behaviour, which have to induce an increase in the student's awareness of behaviour, and to evoke the central steering question.
Furthermore, we designed a sequence of learning and teaching activities (LTAs). Table 14 presents the outline and sequence of the LTAs of the first research cycle, and the outline of the executed curriculum.

Comparison of the intended and executed curriculum provides for issues for further analysis of the scenario. Considering the design criteria, the observation data, evaluation forms, and the comparison of the intended and executed course, the following reconstruction of the LT-strategy of the first research cycle could be made. We will follow the eight design criteria as noted in section 6.2.

Table 14. Outline of the learning and teaching activities in the first research cycle. The last columns present the sequence of the LTAs per lesson as executed in the first research cycle on the four case studies at the pilot schools [1a = De Passie, 1b = Driestar College, h=havo and v=vwo, see section 7.1]

Phase	Lesson	LTA	Description of the LTA	Executed curriculum LTA - [1a_h]	LTA - [1a_v]	LTA - [1b_v]	LTA - [1b_h]
Focus	1.	1.1	Introduction of behaviour by watching videos of animal behaviour	1.1	1.1	1.1	1.1
		1.2	Class discussion about the importance of behaviour, resulting in the steering question for next practice about caring for your pet.				
Acquisition	2.	2.1	Orientation on the first practice: Caring for your own pet	1.2 2.1 2.2 2.3	1.2 2.1 2.2 2.3	1.2 2.1 2.2 2.3	1.2 2.1 2.2 2.3
		2.2	Defining the relationship between humans and animals				
		2.3	Orientation on aspects of welfare of animals: physical and mental health of animals, including the possibility of the exhibition of natural behaviour				
	3.	3.1	Exploring natural behaviour of pets	3.1 3.2 3.3	3.1 3.2	3.1	2.3 3.1 3.2
		3.2	What if natural behaviour is not possible? Exploring the concept stress.				
		3.3	Viewing learning dogs - adaptation to a changing environment				
	4.	4.1	Examining learning processes, working on a practical research	3.3 4.1	3.2 3.3 4.1 4.2	3.1 3.2 3.3 4.1	3.3 4.1
		4.2	Reflection on the first practice				
	5.	5	Practical assignment about learning processes	4.1 4.2	6	4.2	4.2
Extension	6.	6	Orientation second practice- Welfare and natural behaviour of farm animals	6	7	6	6
	7.	7	Confrontation with the physical reactions to stress	7	5	7	7
	8.	8	Practical assignment: design a pigs stable: Pork Plaza	5	8	8	8
	9.			8			
	10	9	Presentations of the created Pork Plaza (also reflection)	8	8	9	9
	11.	10.1	Orientation third practice - Senseless violence	9	9	11	11
		10.2	Elaboration of aggressive behaviour				
		10.3	Confrontation with violence in schools				
Test	12.	11	Written test about aggressive behaviour	11	11		

The use of authentic social practices should result in an increase of student's motivation (design criterion 1), because of their relevance for students. However, in the evaluation, students did not report their thoughts about the practices, but rather about the educational approach. Students reacted positive about the use of videos and the diversity in learning activities. However, many students both at havo level (51%, data source: students' evaluation) and vwo –level (71%, data source: students' evaluation) level judged the content level of the scenario as too low, such as the following quote illustrates:

"The level could be higher. Sometimes, I missed the depth. (…) Which hormonal substances go together with behaviour? To what extent is behaviour hereditary? The cortisol story began with this, but there was not enough explanation." [1b_v, evaluation, Eline]

Students are correct in their observations, because this first version of the design contained only life-world and professional practices. No scientific practices were included, wherein the 'cortisol story' needed to be explored.

Participation in an educationally appropriate authentic practice should increase students' activity (design criterion 2). In particular, designing a welfare friendly stable is an appreciated assignment by students.

One of the main characteristics of the problem posing approach is that motives or steering questions should be developed (design criterion 3). At this point, the design does not meet this criterion sufficiently. The transcription of the reflection activity in the focus lesson revealed a mistake in the design, because no adequate motive for the central steering question was evoked by the LTAs. Students articulate this point in terms of 'not clear what to learn', as is illustrated with the following quotes:

"The answers which one could give were a little wide. One could fill in so many answers, that one could not think: this answer is really correct." [1b_h, evaluation, Johanneke]

"…the learning objectives were not clear. You did not really know why you took these lessons" [1b_v, evaluation, Nelske]

Because of an insufficient development of the central steering question and an inadequate conception of Tinbergen's questions as structuring perspectives, the focus lesson negatively influenced the remaining parts of the scenario. In addition, adequate reflection partly requires an evoked steering question, but has to evoke new questions, as well. However, the reflection phases that were built into the scenario were mostly directed by the teacher, so the students did not develop new motives. We also observed that reflection phases were scarce, because of a lack of time. This lack of time had three causes. First, the time spent, and the sequence of the LTAs in the executed scenario did not correspond with what was intended. For example, students [1a] studied the videos in $LTA^{1.1}$ individually, which took more time than students [1b], who studied the videos collectively in classroom. However, since in both cases $LTA^{1.1}$ took too much time, reflection ($LTA^{1.2}$) had to be executed in the next lesson. In class [1b_h], $LTA^{2.2}$ was divided over two lessons and lesson number 3 of class [1b_v] was filled with a long reflection on the former lesson. With three or more LTAs during a lesson, the last LTA could be only partially executed, which occurred for example with $LTA^{3.3}$ [1a_h].

Second, the inexperience of teachers and students with the concept-context approach, and the limited instruction by both the teachers' manual and the researcher did not yield the desired results. Reflection activities on the second practice (LTA$^{4.2}$) were too short at De Passie [1a], and therefore at Driestar College [1b] we emphasised these activities while instructing the teacher. However, because of improvisation by the teacher, the reflection activities were often longer than intended. Moreover, observations showed that teachers did not demonstrate the intended interactive teaching, and improvised several times during lessons. They told their students: "do this, and do that", so that students consequently did not develop motives for further learning. We expected that teachers would be able to understand and apply the educational approach because of their professionalism, so we instructed them in terms of "You should do…" instead of "You have to follow the scenario and teachers' manual..." Therefore, improvising during lessons by the teachers is mostly caused by the limited preparation of the teachers themselves. Another example of improvisation is the practical assignment in [1a, LTA$^{4.1}$]. Execution of the practical assignment on behaviour of rats was only possible at De Passie [1a], because a rat keeper was willing to come to school.
Third, time pressure in both schools indicated the number of available lessons was insufficient. Lessons at De Passie [1a] last 45 minutes, those at Driestar College [1b] last 50 minutes. At De Passie 12 lessons were available for this case study, and at Driestar College 11 lessons. Because of time pressure, the LTAs$^{10.1\text{-}10.3}$ were not executed. Through restrictions in school organisation the amount of lessons was too small for a well-elaborated test context. Instead of a test context, students at both schools made a summative test.

Because of the poor performance of the reflection activities recontextualisation (design criterion 4) was impossible. For example, students expressed their amazement about the test, because they learnt about pets and farm animals, and did not expect a test about human aggression.

The criteria on behavioural biology (design criteria 5-7) in the first design were subordinate to the first four criteria. Indeed, when 'how to learn' is not adequate, 'what to learn' is not effective. Links between behavioural biology and other biological disciplines were only occasionally indicated (design criterion 5). Links are not always possible or eligible because of the steering question of the practice. A link to physiology was made in the second practice, but, as we described before, elaboration should have had more depth.

Taking the quotes of students into account about the level of the lessons and the lack of clear learning objectives, it could be imagined that students did not understand the complex nature of behaviour and were unable to attain systems thinking (design criterion 6). Because of the mistake in the scenario of the first lesson, students did not attain the understanding of the three perspectives on behaviour, function, causation and development (design criterion 7), very well either.

Summarising, from this reflection on the first version of the design the following four shortcomings were distinguished:

1. A mistake in the design of the focus lesson, including an insufficient explication of the three perspectives on behaviour, resulted in a poorly developed central steering question.

2. An unbalance between the required and available lesson time.
3. A lack of profoundness, particularly at vwo level, resulting in a decrease of the motivation of students and a superficial conceptualisation of behavioural biology.
4. The limited number of reduced reflection phases in the scenario obstructed recontextualising.

Adaptation of the first design

The inventory of shortcomings of the first version leads to the following four main points of adaptation of the design.

1. Since the shortcomings of the focus lesson played out in the rest of the scenario, we completely renewed the focus lesson:

- Instead of viewing videos on behaviour of six animal species, a video of one animal species was shown, showing the unexpected behaviour of a dog. The aim of this change is to focus students' attention on a single well-known animal species. The unexpected behaviour of this animal should evoke awareness of behaviour and evoke the central steering question.
- The classroom setting of the focus lesson changed from individual to group. From the different approaches of the pilot schools, we learnt that group viewing of and discussion about a video is a more productive method to develop awareness of behaviour.
- The focus lesson is prescribed in detail in the teachers' manual (see for example table 7). Strict guidance may diminish teachers' improvisation, and limits the time needed for the focus lesson.
- In order to create a non-interrupted storyline, the focus lesson is included in the first practice, which also connects it with caring for pets.
- At the end of the focus lesson the three perspectives of Tinbergen are explicitly expressed to structure the following practices.

During the revision of the focus lesson, a draft of the improved lesson was tried out with a small group of students (7 vwo students, 15 years old at De Passie [1a]). From this try-out, the lesson was fine-tuned and possible answers to questions were collected and written into the teachers' manual.

2. The scenario is enlarged to 12 lessons and LTAs are more compact to save time for a test practice, and to increase the challenge for students. Some LTAs are prescribed as homework.

3. Different second practices are selected for havo and for vwo students, to increase the challenge and profoundness for students at vwo level. At vwo level as second practice ‘researching the overtraining syndrome’ is selected. Restrictions are made in the first practice by focusing on keeping a dog as a pet, rather than multiple examples such as dogs, hamsters, rats and ferrets.

Another important adaptation in the scenario is the addition of the General Adaptation Syndrome (GAS or stress mechanism) in all educationally appropriate practices, aiming to provide for an adequate understanding of the concept STRESS. The idea of using the GAS arose with the design of the lessons about the practice ‘researching the overtraining syndrome’, where it was quoted in a thesis about this research (De Graaf-Roelfsema, 2007). It can be seen as the ‘missing link’ in the scenario, because it connects behaviour with physiology. Therefore, the use of the GAS satisfies the need for profoundness in the scenario and enhances the coherence of behavioural concepts.

4. Reflection phases are structured through the introduction of concept mapping, providing a basis for recontextualisation and systems thinking. After the discussion of each perspective, a short moment of reflection is incorporated as a kind of summary.

8.2 The second research cycle

Following the adaptation of the scenario and learning materials, the second scenario was tested in the second research cycle. Table 15 presents the outline of the LTAs in the second research cycle.

Table 15. Outline of the lesson plan for learning and teaching behaviour in the second research cycle. For an explanation of the phases and description of the practices, see section 5.3.

Phase	Lesson	LTA	Description		
			HAVO	VWO	
Focus	1.	1.1 1.2 1.3 1.4	Introduction of the subject by observing unexpected behaviour of a dog should result in the development of a steering question, and studying an article about behaviour of wolves provides for the exploration of the three perspectives (function, causation, and development) on behaviour and practices.		
Acquisition	2.	2.1 2.2 2.3	Studying welfare of animals is homework and the 2nd lesson starts with the focus on natural behaviour The function of behaviour is elaborated in group and class discussion		
	3.	3.1 3.2 3.3	What if natural behaviour cannot be performed? Studying causation of behaviour by looking at stress in dogs and the introduction of the General Adaptation Syndrome. The emphasis is on the normal reaction to stressors (acute stress).		
	4.	 4.1 4.2	How to adapt to stressors? Studying adaptation to environmental factors by learning processes. The development of behaviour is seen in the growing process from juvenile to adult and in the learning of a special task for a dog.		
	5.	5.1 5.2	Reflection on the first practice by designing a concept map and introduction of the next practice: designing a welfare friendly stable.	Reflection on the first practice by designing a concept map, and introduction of the next practice: researching the overtraining syndrome.	5.1 5.2

Phase	Lesson	LTA	Description		
Extension	6.	6.1 6.2	Discussion about the welfare and stress of farm animals. A part of it is homework for the next lesson. With the help of an embedded practice, the stress mechanism is studied. The emphasis on the stress reaction is now changed to chronic stress.	After discussing the homework about overtraining in exercise, a behavioural research assignment is prepared by discussing the physiology of the stress mechanism (hormonal cycles). The emphasis on the stress reaction is now changed to chronic stress.	6.1 6.2 6.3
	7.	7	Working in small groups on designing a welfare friendly stable	Discussion of the homework about the stress mechanism and the General Adaption Syndrome Preparing the behavioural research assignment with the Novel Horse Test (NHT)	7.1 7.2
	8.	8	Working in small groups on designing a welfare friendly stable	Executing the NHT assignment in small groups	8
	9.	9	Presentations of the designs of the pig stable	Executing the NHT assignment in small groups	9
	10	10.1 10.2	Reflection on the practice and introduction of the test practice about dealing with human aggression		
Test	11.	11.1 11.2	Constructing a concept map about aggression prepares for writing the essay Executing the final assignment by watching a video about riots		
	12.	12	Executing the final assignment, writing the essay		

The lesson series of the second research cycle consists of twelve lessons. However, looking at the execution it is observed that at havo level the actual amount of lessons was ten ([2b_h]) and eleven ([2a_h]). At vwo level, the lesson series was extended to fourteen lessons. We observed the following causes:

- In [2a_h] and [2a_v] the lessons were distributed in weekly blocks of two lessons and a single lesson. Consequently the LTA for homework could not be executed as intended, and an adjustment of the time needed for the execution was impossible. Therefore, after the first five lessons a lag was piling up. Furthermore, both teachers passed over the reflection time on the development of behaviour.
- It was planned to round off the lesson series just before a holiday, and because of the accumulated shortage of time at [2a_h] the third practice was executed in a too limited amount of time and only a few essays were handed in.
- In [2b_h] the lessons were planned at the end of the school year, and no further lessons were available. The construction of the first concept map (LTA[5.1]) took a lot of time. Therefore, the assignment of the designing of the stable was passed over.
- In all classes a discussion about the General Adaptation Syndrome was inserted, because it appeared to be necessary to explain briefly the stress mechanism.

- At vwo level, in [2a_v] and [2c_v], more time was available, and the whole intended lesson series was executed in fourteen lessons.

How did the execution of the lesson series in the second research cycle proceed? In order to present a coherent image of the lessons, based on the observations, we give an overview of the course of case study 2c_v. The actual analysis is described in chapter 9.

At the start of the first lesson the teacher introduces the researcher, who tells that the lesson series is part of an investigation in a search to an adequate learning and teaching strategy on behavioural biology, and emphasises the importance of the answers of the students. Therefore, he asks them to fill in the workbook accurately.

The teacher shows, according to the teachers' manual, the first part of the video about dog behaviour. The students think about the question of what they saw. In the discussion a student, Stijn, knows a lot about dogs, because he has a dog himself. Nevertheless, after viewing the second part of the video with the unexpected behaviour, Stijn complains that he no longer understands the behaviour of the dog.

Not all prescribed assignments are completed by students and teacher, such as thinking about a possible explanation for what students have seen about dog behaviour. Nevertheless, in a class discussion students conclude that they have to ask the dog why he shows that behaviour. A dog expert tells on a video about the explanation of a licking dog: this behaviour is a sign of submissive behaviour. So, the question is posed why a dog has submissive, or dominant, behaviour? Students are exploring the article in the workbook about this question. In the discussion the desired answers are given by students, but the classification in the three perspectives is introduced by the teacher. Nevertheless, the perspectives are recognized by students, because they know them from a former topic about doing research.

Lesson 2 starts with a discussion of the homework, and because the teacher asks all the questions, it takes too much time. The discussion is about welfare and natural behaviour. It is remarkable that students also name emotions such as being happy and angry when they speak about welfare. In some cases, the relation between environment and behaviour is mentioned, but never explicitly. In the discussion about natural behaviour students are able to connect stress to the impossibility to exhibit natural behaviour. Have they read that before?

Many answers are given by the teacher, and there is an abrupt change to the assignment 'Flappentap' (LTA[2.3]), asking students to note natural behaviour of some pets. Students execute this assignment enthusiastically (see figure 26), but there is not enough time to complete it. So, the third lesson starts with a look at the posters, answering the question which similarities in behaviour can be found. On the board, terms as FOOD, DEFENCE, REPRODUCTION, and COMMUNICATION are written. However, the classification of the concepts on the board into Feeding, Reproduction, and Defence is given by the teacher. One student spontaneously reacts: "Oh, it is all to survive." The question which perspective of behaviour is elaborated is correctly answered by students: the perspective of function. Thereafter, students work on the assignment about stress in a dog, while the assignment about the General Adaptation Syndrome is given as homework. In the fourth lesson, it appears that students are able to explain the stress mechanism, but one student links the concept WELFARE only to physical well-being.

The following change is to the internal and external stimuli, and students name influences on the habituation of pets, such as environment, contact, character, and history (how is the pet treated before coming to the shelter?). The teacher asks which word could be used for that, and students know: education. Also genetic influences are noted.

Figure 26. Students [2c_v] are discussing about natural behaviour of pets, elaborating the assignment ‘Flappentap’.

The teacher writes on the board: HEREDITY and EDUCATION. Both influence the character of a dog, providing for how a dog behaves in new situations. So, what causes behaviour? Internal and external stimuli! Students are able to name examples of both. Then, the teacher refers to the first lesson, asking in what manner we can look at behaviour. A student directly answers: “causation.” And Shenna, another student, answers with the function of behaviour. A good reflection!

It is time to switch to the next question, said the teacher. "We have seen: education, experiences. Let's look at that. How can behaviour be changed? Should dogs of all ages behave in the same manner?" Students think that it should be so, but that there are differences. With some videos about playing dogs and the article about the developmental phases of dogs, students learn about the development of behaviour by learning processes such as imprinting and habituation. However, some students appear to have trouble with the difference between physical differences between dogs and what behaviour is. Therefore, the teacher emphasises the distinction between observation and interpretation.

Furthermore, when asked what socializing is, Stijn replied: “Socializing is the interaction between humans and animals.” In a class discussion the teacher asks about the development of behaviour, and it appears that students understand that hormones are internal factors that have both a physical and behavioural role in development.

From the developmental phases of a dog to the training of dogs is a small step that students and teacher take without troubles. During a class discussion, a student asks about the behaviour of a sleuthhound: is that acquired behaviour? Well, explains the teacher, with training of all dogs behaviour will be learned, but the trainer relies on the natural behaviour of the dogs.

In the reflection on the nature of the perspective, teacher and students conclude that learning processes belong to the perspective of the development of behaviour.

Meanwhile we arrived in the sixth lesson, in which reflection on the practice takes place. Students try to make a concept map of the practice. Shenna, speaking about her first version, shows that she understands the aim of a concept map and that the used concepts are independent of the practice of taking care for your dog, but that they are related to the topic behaviour. The teacher also explains the aim of concept mapping: to think about behaviour, through ordering concepts. The teacher takes sufficient time to instruct his students in how to produce a concept map.

In the 7^{th} lesson students show their concept maps. Most of them have simple maps consisting of about six concepts, and students think it's a mess when they must link a concept with many other. Nevertheless, when the teacher shows his own concept map, students conclude that he forgot the concept WELFARE.

The next learning and teaching activity is the change to the second practice, using a thought experiment. “Suppose, you are in a stressful situation, for example…” Students are involved, because they all know similar situations of stress.

The article about overtraining is assigned as homework, and in the 8th lesson, teacher and students discuss the relation between overtraining and burnout. They understand that overtraining is a serious problem to research, and the question how to research 'stress' brings the class to the physiology of the stress mechanism. In interplay between assignments in the workbook and class discussion the physiology of the stress mechanism is explored. After that, behavioural research on overtraining with horses is introduced with an explanation about an ethogram and a protocol. In the next lessons, students are working independently with the assignment. However, because of a block of the YouTube site at school, the films of (overtrained) horses have to be viewed in class. Students appear to write down different types of behaviour. Some students have made a list of abbreviations of behaviour, others write down the observed behaviour literally. Meanwhile, the 12th lesson is completed, and an actual reflection on the practice is skipped over. The teacher changes to the test practice with the announcement: "Now we come to what we have learned.", and a student asks what she should learn for the test. So the teacher explains the manner of testing and delivers the workbook for the test practice. The video about an aggressive child arouses laughter, and when asked what happens, Emma answers that she first saw 'freezing' and then comes the stressor. In the class discussion about what happens in the video, it appears that students are able to use behavioural concepts, such as STRESSORS, FIGHT, and FREEZE. They know that the environment could cause stress, and 'that you have to react'.

After that, the students elaborate a new concept map on aggressive behaviour. This map is a basis for the final assignment: writing an essay. When the bell rings, Stijn, a student, has troubles to 'breaking free' from his concept map, because 'every time I discover new connections'. The final lesson (14th) students work on their essays, and after they filled in the evaluation form, data collection of this case study is completed.

An accumulation of facts is no more science than a heap of stones is a house
H. Poincaré

9 Learning and teaching behavioural biology

9.1 Introduction

In section 5.3.3 we defined the intended learning outcome of the LT-strategy for behavioural biology. Students' awareness of behaviour is its main goal of the strategy. This goal is attained when students are able

1. to explain that behaviour is caused by internal and external stimuli,
2. to describe that behaviour is the result of the interaction between the organism and its environment,
3. to determine the function of behaviour,
4. to describe the development of behaviour,
5. to recognize the stress mechanism in the behaviour of humans and animals,
6. to carry out a simple behavioural research (only at pre-university level),
7. to discuss applications of behavioural research.

In this chapter we compare the actual learning outcomes with the learning objectives 1-5 by analysing the students' conceptual development, and evaluating which meanings students have developed for behavioural biology concepts. Learning objectives 6 and 7 could be attained by students as a result of the conceptualization developed through the learning objectives 1-5, because these objectives are skills instead of knowledge, requiring reference to the knowledge of behaviour.

According to design criterion 7 an LT-strategy for behavioural biology education concepts should be structured according to the perspectives of function, causation, and development of behaviour. Therefore, in the analysis of the students' conceptual development we focus on these three perspectives of Tinbergen.

In section 9.2 we describe the outline of the empirical evaluation of the LT-strategy, starting with some findings of the conceptual development from the first research cycle, followed by the outline of the evaluation. In the next subsections we describe the development of the central steering question in the focus lesson (9.3), the conceptual development in the second research cycle (9.4), and the knowledge transition through recontextualising (9.5). In section 9.6 we present a summary and conclusions.

9.2 Outline of the empirical evaluation of the LT-strategy

The aim of this thesis is to search for an adequate LT-strategy for behavioural biology. Therefore, the analysis of research data has to focus on the students' understanding behavioural biology concepts. In this subsection, the outline of the empirical evaluation of the LT-strategy is discussed.

In the first research cycle the lesson series ended with a written test for all students. However, this test was not a well-balanced instrument for testing concepts and recontextualisation for two reasons. First, no authentic practice about aggressive behaviour was explored. Second, the test consists of texts taken from several articles about aggressive behaviour. Consequently, a non-interrupted storyline was not elaborated. Although this written test was not a balanced exercise, the results nevertheless indicated for students' conceptualisation of behavioural biology concepts. Therefore, all vwo students' answers (n=869) of the written test were analysed. This analysis showed that students did not distinguish the three perspectives of behavioural biology very well, which is illustrated by the following quotes:

> "In particular, the function of behaviour can clearly explain what the cause of behaviour is." [1b_v, written test, Anne]

> "{Explain, JvM} the cause of this behaviour through looking at the learning of behaviour." [1b_v, written test, Carina]

> "From the function because it is said that aggression is the cause (and necessity) of a behaviour." [1a_v, written test, Julia]

> "You can divide aggression into three parts: 1. Function: what do you want to make clear with aggression? 2. The reason [causation]: why this aggression (threat) 3. Development: building aggression. (…) We have seen the octopus strangling a shark. Apparently, the cause was that he [octopus] felt threatened and therefore, the function to tell that it was his place and he [shark] did not belong there." [1a_v, written test, Rienk-Jan]

Causation of behaviour from internal and external factors is generally correctly understood, but sometimes students understand causation as the broad reason for behaviour ('the why-question') instead of one of the perspectives. The function of behaviour is seen mainly in giving concrete examples, but the link to survival is not imposed. The concepts FEEDING, REPRODUCTION and DEFENDING are strongly addressed to the lessons, but were rarely used by students in their answers. This also applies to the concept NATURAL BEHAVIOUR. During the lessons, most students have noted correct descriptions of NATURAL BEHAVIOUR and STRESS, and a few students are able to relate the concepts NATURAL BEHAVIOUR and STRESS, as is illustrated with the following statement:

> "Every human being or animal has natural behaviour. You have to express that natural behaviour. If this fails, there is stress. Stress can cause a lot of adrenaline release. Too much adrenaline means that you can be aggressive. You will show a different behaviour than your natural behaviour through stress." [1b, written test, Lisa]

However, not every student understood the relation between the concepts very well, as Lianne wrote, confused over whether aggression could be natural behaviour:

> "Aggression can be in your genes, making something which was actually not natural behaviour and welfare, it still comes in. [1b, written test, Lianne]

The main problem is about the perspective of the development of behaviour as an explanatory model. This concept should be clearly defined. Development is often confused with the causes of behaviour, which is illustrated by the following quotes:

> "The development of behaviour comes through the external factors, which influences the internal factors very much." [1b_v, written test, Elsbeth]

> "(…) you also undergo developments of this aggression. It is also reunited with the internal and external factors." [1a_v, written test, Judith]

"Your environment also plays an important role in the development of behaviour. Are you haunted? Then, your behaviour shall certainly react. (…)" [1b_v, written test, Lydia]

Considering the results of this analysis, it is concluded that students express incorrect connections between Tinbergen's perspectives, sometimes caused by handling different descriptions of the concepts. Furthermore, students mention concrete examples and do not show an understanding of the abstract concepts.

In chapter 8 we described the adaption of the scenario. Two important aspects of the used educational approaches are the development of steering questions (motives) and recontextualising, which in particular are the issues of the adaption of the design as described in the former chapter.

From the first research cycle, we learned the importance of the focus lesson, and the evaluation of the first research cycle showed that the development of the central steering question in the focus lesson was not appropriate, and consequently the complete lesson was redesigned. Therefore, the question should be asked whether the adaptation led to an adequate *development of a central steering question in the focus lesson* (design criterion 3), focusing students' attention adequately on the three perspectives on behaviour.
After all, the LT-strategy should lead to an adequate conceptual development of behavioural biology, and the goal of the strategy on behavioural biology education is that students are aware of behaviour (design criteria 5, 6 and 7). Furthermore, from the evaluation of the LT-strategy in the first research cycle (see chapter 8), we observed that a lack of profoundness, particularly at vwo level, decreased students' motivation and resulted into an insufficient conceptualization of behavioural biology. After execution of the second version of the design in a new research cycle, the question is how students' *conceptual development* has to be evaluated.

Because of the presumption that the meaning of concepts is determined at least to some extend by the context, *recontextualising* adapts the meaning of concepts (design criterion 4), and therefore, the LT-strategy consists of three practices. An adequate conceptual development requires an effective recontextualisation. Based upon the evaluation of the first version of the LT-strategy we have argued that recontextualising by students was not attained in the first research cycle. To achieve recontextualising, the scenario was adapted by the introduction of another practice at vwo level, the introduction of the stress mechanism and the use of concept maps as reflection tool. It is understood that what happens as the students change to a subsequent practice should be points of interest about recontextualising. Furthermore, to recontextualise, motives must be evoked providing a non-interrupted storyline and the use of embedded practices should elicit motives. Therefore, it would be interesting to see to what extend these embedded practices provide for evoking motives.

Summarizing, in the next sections we will focus on the following three themes

1. The development of a central steering question in the focus lesson. (section 9.3)
2. The analysis of students' conceptual development, structured according to its components interaction, reflection and construction. (section 9.4)
3. Knowledge transition by recontextualising. (section 9.5)

9.3 The development of a central steering question in the focus lesson

In the focus lesson the central steering question (see figure 19) should be developed from the interaction between teacher and students. From the execution of the scenario in the first research cycle, we learnt that an insufficient development of the central steering question has a strong influence on the remaining part of the execution of the scenario in classroom. It may be expected that a question will be evoked when students experience a problem. Therefore, every LT activity cycle in the problem posing approach starts either with a question or with posing a problem or point of interest. From the prior research on students' ideas about behaviour, we learnt that students are generally not aware of behaviour (Van Moolenbroek, Boersma, & Waarlo, 2007). Therefore, the first learning activity must problematize the phenomenon of (animal) behaviour.

In the first research cycle course of the focus lesson was quite problematic. Reflecting on the nature of the problems, we ascertained that teachers had much opportunity for improvisation, because of a lack of a pre-programmed class conversation in the teachers' manual. The following part of a reflection phase in the first research cycle, after seeing the videos about animal behaviour, illustrates both improvisation by the teacher and the students guessing the teacher's intentions:

T: "What did we do in the last lesson?"

S: "We worked at the computer."

T: "Is that what you remember?"

S: "It was about animals."

S: "With that Komodo dragon."

S: "Squid!"

S: "Then the wild boar began to grunt."

T: "You had to answer two questions. Which two?"

S: "What do you see, and why do they do that?"

T: "If I would compare your answers, which question got the most different answers?"

S: "Why do they do that?"

T: "How does it come?"

S: "Everyone see the same, yet? I do not see green and Peter is not seeing blue."

(…)

S: "Everyone draws his own conclusions."

T: "Everyone draws his own conclusions. That is the most difficult? What was your most difficult question? What do you see or why?"

S: "Why!"

S: "'What you see' is not difficult."

S: "You do not have to think."

T: "Okay, so why is that important?"

S: "It seems to me that it is more important than why they do what you see."

T: "Why is that important?"

S: "Maybe you better understood."

[1b_h, audio, reflection lesson 1]

A second problem in the focus lesson was the wide variety of animal species. Because of this variety, students focused on the animals, and not their behaviour. Both the animal species and their behaviour were unknown to the students.

A third problem is the question asked while observing behaviour. Students were asked why they think that the animal exhibits that behaviour, and that is precisely the question which has to be evoked. Moreover, we suggest that if any question evolves it should be this question.

The last problem we found is that none of the perspectives of Tinbergen was developed adequately. Therefore, the general conclusion was that the focus lesson had to be structured more strictly by the teacher and the learning materials. Both were adapted in the scenario of the second research cycle. The focus lesson is strictly prescribed in the teachers' manual, while the content of the lesson is limited to the behaviour of dogs, forming a continuous story with the first practice. Figure 22 presents the storyline of the first lesson of the scenario in the second research cycle, and table 7 shows the teachers' manual of the first lesson. In the manual, the following learning objectives for this lesson are indicated:

- Students must be able to explain the difference between observation and explanation.
- Students must be able to indicate the importance of behavioural research in order to explain behaviour.
- Students must be able to formulate the three perspectives of Tinbergen (causation, function, and development).

In the following reconstruction of the focus lesson, we analyse the question if students develop adequately the central steering question and attain the learning objectives. The phases indicated in the following analysis refer to the phases of the problem posing approach (see section 2.4.1).

Orientation phase

Intended scenario

The orientation phase aims at orienting and evoking a global interest in behaviour. First, students orientate on behaviour and the difference between observation and explanation. In the intended curriculum, the teacher starts the lesson by referring to the involvement of students with pets. The teacher introduces the subject behaviour by letting the students observe a video on the behaviour of a dog and his owner. Their heads are close together and the dog lifts his lips and is growling (figure 27, left). Students were asked to describe what they saw and what they think about it (observation and explanation). In the discussion about the answers of the students, the teacher asks students how they know if their answer is correct.

Figure 27. Pictures from the video showing a dog and his owner close together (left) and showing the dog licking his owner (right).

After the first orientation, teacher and students narrow down this interest by predicting the end of the video. Students will interpret the behaviour of the dog as angry and do not expect a licking dog (figure 27, right). This unexpected behaviour evokes the question of why the dog is doing this, which is the question about the meaning of behaviour.

In the *execution of the scenario,* after seeing the video about the man and the dog, a class discussion took place as indicated in the scenario. Teacher [2a_v] asks the students to read the learning objectives and activates students' prior knowledge by linking the approach of the lesson series to a former lesson series about amorousness. In the group discussion he explains the difference between observation and explanation. He strictly structures the discussion. Students, answering the question what they thought about what they saw, say that the owner comes into the territory of the dog, while one student notices the interaction between the dog and his environment. The students react enthusiastically on the questions of the teacher.

In class [2a_h] some students have heard about the first video from a parallel class, so the dogs' behaviour is not unexpected anymore. Their teacher passes over the question after the difference between observation and explanation. Students show noisy and restless behaviour.

Students [2b_h] compare what they saw with their own experiences with dogs or are empathic, as the following quote illustrates:

> "The owner sits with his head near the dog. I would not be happy, either." [2b_h, lesson 1, audio]

Their teacher [2b_h] is not using the answers of students in the class discussion to let them think about behaviour, as the following quote illustrates:

> T: "A few things…, you see, the man acts and the dog reacts. He shows his teeth. (…) some of your answers were: "That dog is angry." Did you really see that?" {*Instead of: why do you think that? JvM*}
>
> S1: "It showed its teeth"
>
> S2: "Yes, you do the same when you are laughing!"

S3: "That woman with Bokito[22] thought the same!"

[2b_h, audio, lesson 1]

Although no steering question about the difference between observation and explanation is evoked and the teacher answers the question about the difference himself, students [2c_v] describe dogs' behaviour adequately:

"A growling dog showing its teeth, next to the head of a man." [2c_v, workbook, Michelle]

Although not all students did:

"A man beside an angry dog." [2c_v, workbook, Arthur]

One student, Stijn, knows a lot about the behaviour of dogs, because he has a dog himself. After seeing the video, he says that he is not understanding it at all. However, he knows how to explain the behaviour of the dog:

S: "Perhaps, the man is higher in rank."

T: "That man has a higher rank?"

S: "Yes, I can explain, Mister."

T: "Okay, go on."

S: "Dogs live in a herd, yet? Well, perhaps that the man has a higher rank in the herd."

[2c_v, audio, lesson 1]

Then, the teacher induces the need for behavioural research by saying:

T: "How could we know the explanation of this behaviour? (…) If we really want to know, we should ask the dog. There we have a problem!" [2c_v, audio, lesson 1]

Consequently, we conclude that students [2c_v] have adequately problematized the concept BEHAVIOUR.

Students of class [2a_v] also have similar reactions. They are amazed about the dogs' behaviour and seek for explanation.

S1: "It does not harm its owner."

T: "(…) anxiety! Kevin?

S2: "It just wanted to see who it was; or a potential danger."

T: "Okay, that is a nice explanation. Eh, how do we really know what happens here? (…)"

S3: "by doing it with an unfamiliar person."

T: "okay, we are going to change the environment. Excellent idea. (…) What is an even better method?"

[22] On the 18th of May 2007 a big Gorilla called Bokito escaped from his home in the Zoo in Rotterdam (the Netherlands). http://www.metacafe.com/watch/605817/the_great_escape_of_gorilla_bokito/ (Retrieved February 2012)

S4: "another dog?"

T: "Yes. But the most obvious option is not yet named? (…) Who could you ask what happens?"

S3: "The dog himself!"

[2a_v, audio, lesson 1]

Then, the teacher refers to a 'dog whisperer' who could understand 'dog language', and contrasts this with the scientific research methods and introduces a dog expert on the next video.

From the written answers in the workbook to the questions regarding the views and thoughts of students after watching the first part of the video, it appears that most of the students gave the correct answers.

Students expect that the dog bites the man, because it is angry. After seeing the end of the video, students mostly explained the licking of the dog in affective, anthropomorphic terms, as illustrated by the following quotes of worksheets:

"It is not scared, it trusts its boss"

"It is playful" {several times noticed}

"It shows he is a friend"

"To take attention"

"To show it is not angry en loves its boss"

"It trusts that man. It feels the man wants nothing wrong. Therefore, it licks to show it accepts him"

[2b_h, lesson 1, several worksheets]

"Because it {the dog, JvM} wants to apologize, because it growled against a dominant and higher placed person"

[2c_v, workbook, Vivanne]

Students and teachers use anthropomorphic language, but none of the teachers corrected students when using such terms.

Activity phase

Intended scenario

After orientation, learning activities in the activity phase ought to give a more specifically formulated need-to-know, to extend their prior knowledge. The scenario prescribes that the teacher asks students how we know the meaning of that behaviour. Animals do not answer to that question, so it must be investigated by research or asking an expert. The students have to conclude that the explanation of the behaviour of the dog could be acquired by research:

"Our expectations are linked to our human experiences. We think for that dog. That is the problem of a researcher too." [2, LTA[1.2], scenario teacher activity].

The teacher suggests listening to an expert on dog behaviour. Students learn that the licking of the dog is a sign of submissive behaviour. The teacher asks students why a dog has submissive (or/and dominant) behaviour. Students read an article about dominant and submissive behaviour of dogs, applying and extending their knowledge from the former LT-activities. The article explains the indicated behaviour from several perspectives and students are asked to find these explanations.

The *executed scenario* evokes an important conclusion, because nearly all teachers passed this part of the LTA[1.2] over. The change made by the teachers, from the concrete life-world practice to a scientific practice to make students aware of behavioural research is either not explicitly made or not made at all. The question is how do we know the meaning of behaviour? Three teachers forgot to ask their students about behavioural research as a tool for understanding the meaning of behaviour. Teacher [2a_h] poses that behavioural research is conducted to explain behaviour. Thereafter, she changes to the second video about the explanation of a licking dog.
Teacher [2b_h] discusses the assignment in the worksheets and checks the answers to the question on the explanation of the licking dog.

T: "Was it expected that the dog would do this?"

S: "It was expected by the man, indeed"

T: "Are we inclined to look after such situation through our own ideas, thoughts and views? How can we get an answer to the question why that dog is doing that?"

S: "Ask the dog!"

[2b_h, audio, lesson 1]

After that, the teacher forgets to refer to behavioural research, and starts the next video with the dog expert.

Teacher and students [2c_v] pass over question 3 of the workbook. In the class discussion about how to explain the dogs' behaviour, students conclude that they should ask the dog in order to understand its behaviour.

The transition to the next LT-activity, reading a text about dog behaviour, is more or less self-evident. The teacher switches the attention from the man-dog relationship to a dog-dog relationship, and the students [2b_h] make the switch easily. One student quotes the example of wolves, which live in a herd, and the teachers introduce the next LT-activity. Teacher [2a_h] introduces this activity more abruptly, without evoking a motive by asking the questions as indicated in the teachers' manual, as the following fragment shows:

T: "We then read a text about submission and dominance, because these are two things that belong together."

[2a_h, audio, lesson 1]

Class [2c_v] views the video of the dog expert, but the students' discussion about their answers is passed over and the teacher instructs his students for the next LT-activity, to read the text.

Despite passing over the embedded practice, the storyline is not disrupted, and it was concluded that the time taken for LTA[1.2] can be reduced.

<u>Reflection phase</u>

Intended scenario

In the reflection phase, a class discussion results at categorization of the students' explanations according to the three perspectives of Tinbergen: causation, function, and development. This last phase in the focus lesson connects the central steering question with the next practice. Teacher and students have to conclude that more knowledge about the perspectives is needed, which will be explored in the next practices. Students confirm that they can better care for their pets when they know more about the meaning of their pets' behaviour.

In the executed scenario, after reading the article “Dog behaviour: submissive or dominant?” all classes discuss the written answers. Students have to find the different categories of explanations of submissive and dominant behaviour of dogs, but classification into the three perspectives is not done in class [2a_h], because the teacher [2a_h] did not follow the teachers' manual. The teacher discusses answers with the students, writing it on the blackboard, referring to her experiences with her own dog, writes the perspectives on the blackboard and asks students to categorize the explanations found. Students show to be able to classify the explanations. After the discussion, the teacher asks the students to start their homework, so no new steering question is elicited.

In contrary, in class [2b_h] after writing possible explanations on the board, mentioned by the students, the teacher [2b_h] wants to conclude:

T: "When we look at these points, are these explanations of the same order? Do they show the same kind of explanations?"

S: "Of course not."

T: "(…) If you relate a question to these explanations?"

S: "What a dog already has, and what a dog must learn."

T: "What does it have?"

S "Hormones, testosterone."

T: "Which question could you ask? Then, you are investigating behaviour. (…) That hormone causes what? Then there is the question of causation."

[2b_h, audio, lesson 1]

From the abovementioned fragment it could be concluded that the teacher did not follow the manual, and therefore had to give the answers about the perspective of causation by himself. Nevertheless, when the students understand what the teacher means, they are able to characterize other explanations, although the teacher gives the correct names to the different perspectives.

Teacher [2a_v] prepares the class discussion by dividing the board into pieces. After writing the explanations on the board, the teacher asks the students which words must be written above the pieces:

S: "Function."

S: "Origin?"

S: "Aim."

T: "And, how do you name this one?"

S: "Education"

T: "Yes, exactly, and since we deal with behaviour, it will be named development."

[2a_v, audio, lesson 1]

It shows that students are able to understand the correct perspectives. In addition, the teachers [2a_h and 2a_v] refer to the former lesson series about amorousness and the role of the hormone testosterone. Some students are surprised about the influence of testosterone in the womb on behavioural development.

In class [2c_v] the question of which explanations for behaviour belong together, is passed over. However, we observed that students recognized the three perspectives, since they have learned these in the biology lessons before, where research in general was the subject. The teacher tried to evoke the recollection, as appears in the following fragment:

T: "When I ask the question why a dog is submissive and dominance, what do you remember from this question? Think about the former chapter about research questions. How do you distinct this? What was the matter with the 'why-question'?

[2c_v, audio, lesson 1]

Thereafter, students' explanations on submissive and dominant dog behaviour found in the article are written on the blackboard, and it is observed that the students developed the three perspectives laboriously.

Then, the first lesson is passed, but because of double lesson time in class [2a_h], the second lesson started immediately. The teacher [2a_h] started the second lesson with the following statement:

"(…) we have seen that there are three categories recognised to explain behaviour, why there is behaviour. It has a function, it has been caused by something and it arises …"

[2a_h, audio, lesson 2]

Next, she informs the students about the next practices. The same procedure is followed by teacher [2b_h], who also gives a review on the three perspectives in the next lesson. Although this procedure is prescribed in the teachers' manual, the change to the first practice is not motivated by a content-specific motive. However, the first practice is an extension of the focus lesson, and the steering question of the first practice (how to care your dog) is a logical question after the focus lesson.

Summarizing, the focus lesson intended, first, to increase students' awareness that behaviour is a biological subject, resulting in the development of the central steering question, and second, to develop the students' awareness of the perspectives of Tinbergen. To attain these objectives the didactical approach in the second version of the LT-strategy contained the following four elements:

1. Students observed unexpected behaviour of a well-known animal, a dog.
2. Students explored possible explanations for this unexpected behaviour, and categorized these explanations according to the three perspectives of Tinbergen.
3. The subject of the first practice (how to care for your dog) is in line with the focus lesson and creates a non-interrupted storyline.
4. The well-prepared focus lesson is strictly prescribed by the teachers' manual. The teachers were asked to follow the instructions.

From the above-mentioned reconstruction of the reviewed focus lesson we conclude that observation of the unexpected behaviour of a dog increases students' awareness of behaviour as a biological subject, and they are stimulated to investigate why the dog’s behaviour did occur. However, the central steering question, "Why do they do that?" is more implicitly posed by students, but they explored this question by the development of the perspectives of Tinbergen. Consequently, common language for exploring the perspectives in the next practices is constructed. In addition, the restriction to the behaviour of one animal species, the dog, creates a non-interrupted storyline, and it appears that students elicit a motive for exploring the first practice.

Furthermore, we conclude that the teachers' manual provides adequate preparation for the teacher, which is shown by the differences in the course of the lesson when teachers improvised or followed the manual.

Overall, we conclude that the focus lesson of the scenario fulfils to its purpose, and that the adaptation of the scenario was effective.

9.4 Students' conceptual development

Awareness of behavioural biology starts with understanding the three perspectives on the question ‘why do they do that?’ In the former section, we concluded that the focus lesson provides a motive for students to investigate the three perspectives of Tinbergen. In this section the following three questions are answered.

1. How did students understood the three perspectives with their respective behavioural biology concepts? From the interaction in the executed lesson series we will find an answer in subsection 9.4.1.
2. How did the reflection phases contribute to the students' conceptual development? The reflection phases, with the constructed concept maps, must show students' awareness of behavioural biology, and the reconstruction of the reflection is described in subsection 9.4.2.
3. How did concept maps as a reflection tool contribute to the students' conceptual development? Since the use of concept maps as reflection tool is part of the adaption of the scenario, we investigate to what extent concept maps contribute to the students’ conceptual development. In subsection 9.4.3, we analyse both the technical quality of the constructed concept maps, and the use of its propositions.

9.4.1 *Understanding the three perspectives on behaviour in the second research cycle*

In this subsection, we start with an overview of the distribution of concepts linked to behavioural biology and students' conception of behaviour, as found in the students' list of concepts. Thereafter, we describe students' understanding of the three perspectives on behaviour, as appears from data of the observed lessons and the students' workbooks.

As we described in section 7.2 the listed concepts were classified in three categories: behavioural biology concepts (bb), concepts referring to the stress mechanism (sm), and context related concepts (cc). Figure 28 shows the relative frequency of the three categories of concepts per practice. In the first practice, concepts of behavioural biology are introduced, strictly divided into the three perspectives of Tinbergen. In the second practice the stress mechanism is elaborated, whereby the structure of the perspectives is less visible and the emphasis is on the relationship between behaviour and physiology. In the third practice, students have to select concepts by themselves from articles and videos about the practice as sources of concepts. These differences between the practices are reflected in the relative frequency of the three categories of concepts, which underlines, first, that the context determines which concepts are used and needed, and second, that the educational practice (both intended and executed) defines the learning outcome considerably.

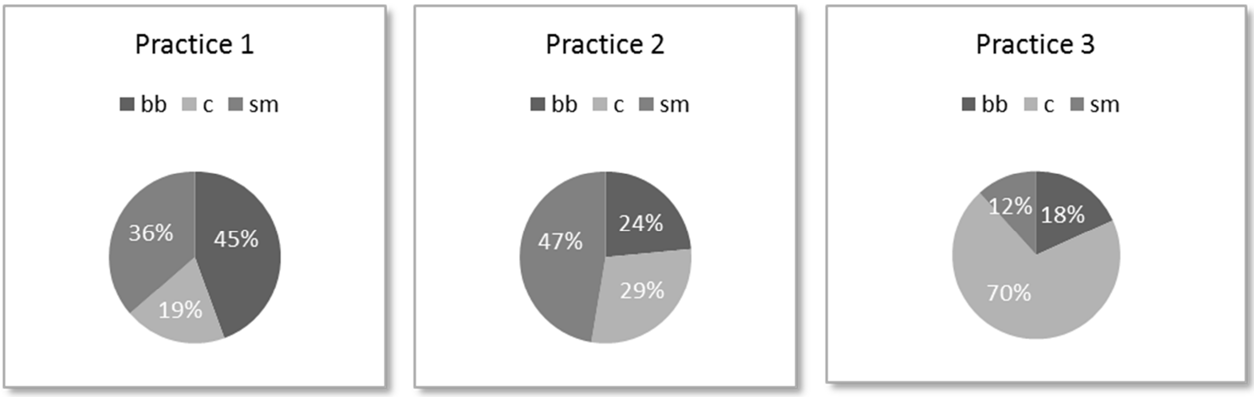

Figure 28. Relative frequency (%) of three categories of concepts listed by students. bb=behavioural biology concepts; c=context related concepts; sm=concepts referring to the stress mechanism. Amounts of concepts Practice 1: n=1065; Practice 2: n=590; Practice 3: n=416. Number of students Practice 1: n=82; Practice 2: n=65; Practice 3: n=39.

Comparing the students' descriptions of behaviour with the definition of behaviour[23] we could conclude that most students correctly conceptualized BEHAVIOUR. Some students only have a general notion of behaviour as "all things an organism does". Other students describe behaviour as 'all things you (or an organism) do', like Anne and Vivianne, [2c_v, workbook P1, Vivianne & Anne]. Other students connect behaviour to stimuli, as the following quotes illustrate:

[23] "The internally coordinated responses (actions or inactions) of whole living organisms (individuals or groups) to internal and/or external stimuli, excluding responses more easily understood as developmental changes." (Levitis, Lidicker, & Freund, 2009, p. 6).

"The reaction to stimuli" [2b_h, workbook P1, Marloes]

"How you react to your environment", [2b_h, workbook P1, Arina]

In the second practice, descriptions of behaviour are focused on animals, instead of organisms, and some students connect behaviour with the function of behaviour or natural behaviour, as is illustrated by the following quotes:

"What an animal does to survive" [2b_h, workbook P2, Rinske]

"An animal shows certain things. That is behaviour, natural behaviour." [2b_h, workbook P2, Daniëlle]

Descriptions of behaviour in the third practice are focused on human beings. "What somebody does" is the common description, and no relation with stimuli is indicated.

However, not only categorizing the concepts gives insight in the kind of concepts that are mentioned by the students. As a design criterion, we have specified that an LT-strategy for behavioural biology should be structured according to the three perspectives. Figure 29 shows the relative frequency of behavioural biology concepts (first category), categorized by the three perspectives on behaviour for the three practices, as it appears from the students' list of concepts.

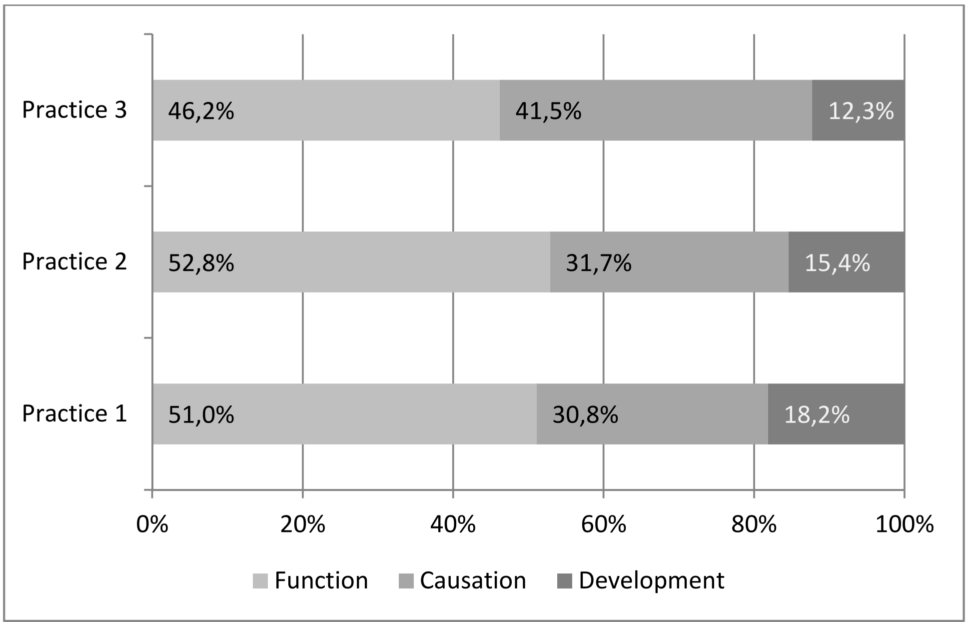

Figure 29. Relative frequency (%) of the behavioural biology concepts as noticed in the students' list of concepts. Number of concepts practice 1: n=429; Practice 2: n=123; Practice 3: n=65.

A few points are remarkable. Students do not often explicitly refer to the three perspectives of Tinbergen, although the few descriptions of the three perspectives that students have noted, are correct. Nevertheless, the self-evaluation of students shows that about 70% of the students recognize these perspectives very well. As mentioned before, in the first practice the structure of the sequence of perspectives is strictly followed in the scenario and visible in the workbook in the headers of the sections. In the other practices, the perspectives are not indicated in the workbook. In the third practice, only students of [2b_h] name the concepts CAUSES, FUNCTION and DEVELOPMENT of behaviour, probably because students were told to use them when making their concept maps. Therefore, from the

quantitative analysis of the list of concepts, it is concluded that most students understand the three perspectives on behaviour.
In addition, the teachers paid attention to the three perspectives in several lessons, in particular during reflection activities. For example, teacher [2a_h] wrote the terms on the blackboard, like teacher [2a_v] who did the same after the first lesson.

Teacher [2a_v] asked the students when changing from causation to development:

T: "Which of the three did we not yet look for?"

Students do not know. Therefore, the teacher tried again:

T: "...sometimes things are developing in time"

[2a_v, audio, lesson 4]

Teacher [2c_v] also paid attention to the perspectives:

T: "I refer to the first lesson. What was the first question to answer? We explored a few manners to examine behaviour."

S1: "Causation!"

S2: "Function!"

T: "What was the function of behaviour?"

S3: "Survival"

[2c_v, audio, lesson 4]

The above-mentioned fragment of the conversation shows that students are able to distinguish the perspectives of function and causation of behaviour. However, it appears that while students sometimes understand the three perspectives, sometimes they do not, and it is not clear what the background of that observation is. A possible explanation could be found in the structure of the class discussion, or in the articulation of the three perspectives, as indicated through the self-evaluation of the students. Table 16 gives the percentages of that evaluation for the learning goal that students are able to explain behaviour according to the three perspectives. The differences in the assessment of the learning goals in the self-evaluation may be caused by differences in formulation. Teachers use other words for perspective, such as explanation or category.
It appears that not all students are able to explain behaviour according to the three perspectives (statement 1). During the reflection on the first practice, this learning goal was formulated otherwise (statement 2). It is remarkable that the average percentages on statement 2 are lower than on statement 1, while the introduction of a concept map in statement 3 delivers more recognition by students. It should be concluded that the choice of words determines to some extend the recognition of the concepts. There seems to be an incomplete labelling of the three perspectives, even while the distinction of the three perspectives of Tinbergen is clear to students.

Table 16. Students' self-evaluation on the lesson series, collected after finishing the lesson series. The statements are made from the formulated learning goals indicated in the teachers' manual.

		Average total		
	havo, n=36	Yes	Little	No
1	I am able to formulate the three perspectives of Tinbergen	50%	32%	18%
2	I am able to explain three ways in which behaviour could be interpreted	25%	44%	31%
3	I am able to explain in a concept map from which perspective we could interpret behaviour	36%	47%	17%
		Average total		
	vwo, n=34	Yes	Little	No
1	I am able to formulate the three perspectives of Tinbergen	38%	29%	32%
2	I am able to explain three ways in which behaviour could be interpreted	29%	32%	38%
3	I am able to explain in a concept map from which perspective we could interpret behaviour	30%	64%	6%

Despite of the afore-mentioned incomplete labelling of the three perspectives by students, other behavioural biology concepts are frequently mentioned, such as STIMULI, STRESS, ADAPTATION, NATURAL BEHAVIOUR, WELFARE, and SURVIVAL (divided into three kinds of behaviour: FEEDING, REPRODUCTION and DEFENCE), as we describe below in the reconstruction of the conceptualisation of the perspectives.

The perspective of the function of behaviour

The function of behaviour is the first perspective students explored. Reasoning from the welfare of a pet, they should understand that the NATURAL BEHAVIOUR of an animal is related to the concept WELFARE. We described WELFARE as the resultant of three components: (1) the physical and (2) psychological state of the animals' attempt to cope with its environment, and (3) the state of naturalness. SURVIVAL is the ultimate function of behaviour. The function of behaviour could be differentiated into FEEDING, REPRODUCTION, and DEFENCE behaviour. In the scenario, the function of behaviour is in particular elaborated in the first practice and to a lesser extent in the second practice.

Students learn about welfare in a homework assignment. The concept WELFARE is introduced through a picture of a website of a dog school. The dog school 'has the aim to increase the welfare of dogs'. Students, who noted the concept WELFARE in the list of concepts, described the three components, although many descriptions do not contain all components. Students understand the state of naturalness as the state to which animals can show their NATURAL BEHAVIOUR, as is illustrated with the following quotes:

> "That it is physically and mentally going well" [2a_v, workbook P1, Paul].
>
> "When an animal is able to show its natural behaviour." [2b_h, workbook P1, Rinske]
>
> "Feel good and show natural behaviour." [2b_h, workbook P1, Josien, Carla]

In the third practice the concept WELFARE is hardly mentioned. Only a few students understand WELFARE as being happy or having as little stress as possible. We conclude that students understand the concept WELFARE correctly, although not all components are noted in one description.

The concept NATURAL BEHAVIOUR is explored in LTA[2.2]. In the classroom five or six posters hang with the name of a pet on top. Students have to describe what kind of natural behaviour of the pet they could remember.

However, not every teacher connects the concept WELFARE with NATURAL BEHAVIOUR. Teacher [2a_h] abruptly made the change to LTA[2.2] by saying: "We are going to do the poster exercise", and discussed the concepts WELFARE and NATURAL BEHAVIOUR afterwards.

Teacher [2b_h] started discussing homework, but the relation between WELFARE and NATURAL BEHAVIOUR is laborious. Indeed, students have problems understanding the concept WELFARE, and reason from their own point of view, as is shown in the following fragment:

T: "Suppose you have a pet. What is important for a pet?"

S: "That it is a bit affectionate."

(…)

T: (…) If you go to buy a pet and you'll think it over, what are you doing? Seen through the eyes of an animal."

S: "It brings a lot of problems with it."

T: "Yes, with that we are now to the central issue. If a dog is not at home, not at his own place, do you have to take him?"

S: "Of course not."

T: "What are you focused on when you think about this? Think about health, think of costs, and also put the relationship here with the work for today. (...) How can you really say it in one word? It's about ...?"

S: “Welfare!”

(…)

T: “Who can explain in a few words what welfare is?"

{There are no answers, thus the teacher refers to question 15 of the workbook}

S: "Living conditions?"

T: "How do you notice that a dog is satisfied?"

S: "Wagging, behaviour."

T: "Behaviour!?"

S: "Not barking, licking."

T: "When I write this on the blackboard, what do I mean with this?"

{Teacher writes 'natural behaviour'}

S: "Character?"

S: "How it responds as a beast."

T: "To what?"

S: "To its environment."

T: "Then it responds in a normal, natural way to his environment. And it adapts its behaviour more or less. Where it all is really focused? Why eat? Why good health? Why does an animal adapt to the environment, so it can live? Remember that question, it will be back."

[2b_h, audio, lesson 2]

In the above-mentioned class conversation, the teacher shows difficulties with the relationship between WELFARE and NATURAL BEHAVIOUR. From the home assignment in the workbook, students learnt that ‘freedom' is a characteristic of the welfare of an animal, as well as the freedom to show its natural behaviour. However, the teacher did not refer to that assignment. In addition, this referral is not in the teachers' manual, and should be included.

Unlike teacher and class [2b_h], teacher and class [2a_v] discussed the concept WELFARE, starting with the five freedoms. After students answered questions in the workbook, they discussed the concept NATURAL BEHAVIOUR. Teacher [2a_v] decided to discuss the topic on his own manner, and used the students' answers to attain the objective of thinking about natural behaviour, as illustrated by the following fragment:

T: When an animal exhibits its own natural behaviour that is an indication that an animal is comfortable. Who knows an example of natural behaviour of a dog?"

S: "Eating shit."

[2a_v, audio, lesson 2]

Students are laughing, but the teacher reacts seriously and answers:

T: "You want rancid examples, but it is just one correct example. (...) Animals not see this as a problem. (...) Why would you eat your own poop?"

S: "An improved resistance."

S: "It gets all the nutrients out."

T: "Yes of course (...) a number of posters is hanging in the classroom. The assignment is to write examples of natural behaviour on the posters as much as possible."

[2a_v, audio, lesson 2]

Finally, teacher [2c_v] discussed the homework about WELFARE. Students showed they were able to relate NATURAL BEHAVIOUR to STRESS, as the following lesson fragment illustrates:

T: "I think that welfare is an important concept. What is welfare?"

S: "Your living conditions."

T: "Does that say anything about welfare?"

S: "If they are good or bad."

T: "Then you are already a step further. This may affect their welfare. Does anyone else have a definition? (...)"

S: "If {the dog} enjoys itself, it does not have to handle chronic stress."

T: "What is that?"

S: "Constant stress that {the dog} has, that {the dog} did not feel at ease."

T: "But do you understand what stress is?"

(…)

S: "Some animals can die from stress.

T: "Yes, they do. What is chronic?"

S: "That is constant."

T: "The next lesson, we will continue with stress. Is there another definition of welfare?"

S: "Good physical and mental condition."

[2c_v, audio, lesson 2]

It is concluded that students understand the connection between STRESS and WELFARE, and can give a definition of WELFARE.

LTA[2.2] ends with discussing the similarities between the written down examples of NATURAL BEHAVIOUR of pets. In all classes, students understand that NATURAL BEHAVIOUR is necessary to survive.

T: "What is all this {behaviour} good for?"

S: "To survive."

T: "Right. Behaviour is there to make sure you will survive."

[2a_v, audio, lesson 2]

In two classes, the teacher mentioned the categories of the function of behaviour, FEEDING, REPRODUCTION, and DEFENCE by him/her selves, but in the other classes, students were able to categorize the examples of NATURAL BEHAVIOUR.

Obviously, it is interesting to see what students noted in the list of concepts and the workbook. NATURAL BEHAVIOUR is understood by students as behaviour that is aligned to the natural environment [2a_v, workbook P1, Joost], as behaviour that is specific to that species [2c_v, workbook P1, Roos & Chenna], or as behaviour that an animal shows according to its instinct [2c_v, workbook P1, Emma]. Many students describe natural behaviour as behaviour that an organism naturally shows. Also after the second practice, students articulate comparable descriptions. One student describes NATURAL BEHAVIOUR as ‘uninhibited behaviour' [2b_h, workbook P2, Femke]. However, in the third practice, NATURAL BEHAVIOUR is described as behaviour that is changeless, as the following quotes illustrates:

"Natural behaviour is behaviour without influence of the environment:" [2a_h, workbook P3, Lise-Milou]

"The innate behaviour." [2a_h, workbook P3, Mark]

"Your normal behaviour that is always the same." [2a_h, workbook P3, Mirthe]

However, it is unknown if this description indicates a change in the meaning of the concept NATURAL BEHAVIOUR, because only a few students mentioned the concept NATURAL BEHAVIOUR, and because NATURAL BEHAVIOUR is a concept that is not occurring in the articles of the third practice.

Generally, FUNCTION is considered as a goal. It is described as "what you want to reach", in particular in the third practice from the perspective of humans, where the concept is linked to aggression.
Students understand that SURVIVAL is the function of behaviour. They also understand that all behaviour can be categorized into the categories FEEDING, REPRODUCTION, and DEFENCE.
These observations are supported by the self-evaluation of the students. Evaluating the statement that they are able to name survival as the function of behaviour, 81% of the havo students and 79% of the vwo students answered positively. The other students answered ‘approximately' on this statement.

We conclude that the part of the scenario concerning the function of behaviour is largely executed as intended, although there are some minor deviations. Teachers did not evoke a motive for researching NATURAL BEHAVIOUR in interaction with students, despite of the relevance of LTA[2.2]. However, students understand the concept NATURAL BEHAVIOUR and are able to relate it to WELFARE and environmental circumstances. Furthermore, all teachers took a lot of time (20-30 minutes) to explain and discuss the concepts WELFARE and NATURAL BEHAVIOUR, which was necessary, but not intended. In their feedback, teachers said they felt uncertain, because they did not check very well students’ comprehension of the behavioural biology concepts.

The perspective of the causation of behaviour

The concepts belonging to the perspective of causation are INTERNAL AND EXTERNAL STIMULI, and by extension, the concepts of the General Adaptation Syndrome, the stress mechanism. In the scenario, learning and teaching causation is explicitly planned in the first practice, and in the second practice the physiology of the stress mechanism is elaborated. Therefore, we will first consider students' conceptualizing of the causation of behaviour in the first practice, and then the conceptualization of the physiology in the second practice.

LTA[3.1] about the causation of behaviour includes an article about dog stress with corresponding questions, class discussion about the homework, and an assignment about the stress mechanism. LTA[3.3] ends with an assignment about the relation between dog stress, cortisol, and human interaction (see section 6.3.1). In the executed scenario it appears that some of the teachers have difficulties in changing from the perspective of the function of behaviour to causation. This is illustrated with a fragment of teacher [2a_h] in a class discussion:

T: "Who can tell me again what the natural behaviour of dogs is?"

S: "Behaviour that is naturally innate."

T: "Can you give an example?"

S: "Wag."

S: "Barking."

S: "Tail between the legs."

T: "Natural behaviour when he is afraid. Yes. Do you know what its meaning is?"

S: "Usually it is indicating that it is dominant, it holds the tail up."

T: "Exactly, the position of the tail says something about the ranking. Why was that important again, that ranking?"

S: "Because if there is no hierarchy, there is no group to work together."

T: "You cannot work together. And why is collaboration so important?"

S: "Because you can achieve more together than just by yourself."

(...)

T: "Yesterday, if I remember well, we discussed the three 'V's'[24], but I'm not sure we did so, therefore I repeat it now."

S: "No."

T: "Delineating territory has entirely to do with this." {Teacher pointing to the words 'protect' and 'defend' at the blackboard}

T: "Feeding! Which 'V' even more?"

[2a_h, audio, lesson 3]

Students also named the third V, REPRODUCTION. The teacher spent a lot of time in changing from the concepts of NATURAL BEHAVIOUR and DEFENCE as part of the survival of an organism. Then, the teacher referred to the article, but students did not read it and the teacher started to review it:

T: "What if {the dog} cannot do that {natural behaviour} now?"

S: "If it is trapped."

T: "What can {the dog} not do?"

S: "Play."

S: "Reproduce."

(...)

S: "If {the dog} cannot predict its surroundings"

T: "Very good! When does that happen?"

S: "On holiday."

T: "So in an unfamiliar situation?!"

S: "It's never been there, it has no territory there."

(...)

[24] Dutch 3 V's Voeding, Voortplanting en Verdediging. In English: Feeding, Reproduction, and Defence

T: "I have a dog myself. And when the dog runs loose and runs into the road. It is hit. So injury is a situation in which all these things {3V's, JvM} are no longer present."

[2a_h, audio, lesson 3]

Then, the teacher returns and asks:

T: "Why does a dog do this? What is the purpose of natural behaviour? Why does it eat?"

S: "To survive."

T: "Exactly, natural behaviour is aiming to survive."

[2a_h, audio, lesson 3]

Students are interested in the topic, and have several questions. Nevertheless, the lesson goes on with a discussion about the concept DEFENCE:

T: "We are going on. Because an unfamiliar situation, you are not doing what you want to do, so there is a kind of tension. Another word for tension is stress. Seeing a cat, what can a dog do?"

S: "Bite."

T: "What is covered?"

S: "Protect yourself."

T: "How does he protect itself?"

S: "By attacking. Fighting."

T: "It will defend itself. This can be the meaning of fighting and biting. Is there more?"

S: "Growling."

S: "Running away."

T: "Sometimes safe: running away. Another situation is, (…) is there anything else you can do as a form of defence, except fight or run away, flee?" {The teacher refers to question 28 of the workbook, JvM}

S: "Strange things, like, e.g. being pathetic, attracting attention, weird body postures."

T: "Yes, those are signals. (...) Fight, flight, there is another one in the article: freeze. It is probably the most common. If you and your dog go outside and see a cat, my dog stops.

[2a_h, audio, lesson 3]

From these fragments of the class discussion it appears that it is difficult to change perspective. Students are interested in the topic of behaviour, but have to guess what the teacher wants to hear. The cause of this difficulty seems to be the absence of a steering question, or motive.

Althouhg the questions in the workbook about the dogs' stress are discussed, the concept DEFENCE is still not clear and the teacher's questions provide more of the same. Moreover, many examples that have nothing to do with the topic are added. Teacher and students discuss the difference between acute and chronic stress, and students are able to explain these differences. The teacher knows a lot about dogs, and a lot of time is spent (more than half of a lesson) to tell about her experiences. Nevertheless, in this lesson, the relationship between behaviour and environment is established, but we discovered that the concepts INTERNAL AND EXTERNAL STIMULI are not explicitly mentioned in the first practice. One question asks for a definition of a STRESSOR, while the summary states:

> "Behaviour is caused by internal and external stimuli. Give an example of both based on the article above, and explain how the stimulus influences the behaviour of the dog." [workbook, question 37]

Teacher [2b_h] spends less lesson time about the dogs' stress. Students are able to explain how a dog could behave under stress conditions, as is shown in the following quote:

T: "What do we mean by stress?"

S: "Sensitivity to unknown things."

S: "Or you have to do too much."

[2b_h, audio, lesson 3]

The last student changes the focus from a dog to a human perspective.

Students [2a_v] had a school party the night before and did not do their homework; consequently, students had to read the text about dog stress during the lesson. The teacher discussed the article, starting with the retrieval of knowledge about the perspectives. Students were able to remember the perspectives themselves. The teacher then asked about stress as a cause of behaviour:

T: "What do you need to produce stress?"

S: "Unknown environment."

T: "What else?"

S: "Hard training, combined particularly with punishment."

T: "These are more learning manners, for both humans and animals."

The teacher talks about acute and chronic stress:

T: "What does chronic mean?"

S: "That it is impossible to return to point zero."

[2a_v, audio, lesson 3]

It is concluded that students seem to understand the relation between STRESS and the cause of behaviour. In addition, they describe chronic as a state in which it is impossible to return the point zero.

Teacher and students [2c_v] also discuss the questions about the article 'Dog stress' effectively, since the teacher restricts the discussion to the questions in the workbook and is able to make clear that defensive behaviour could be distinguished in FIGHT, FLIGHT and FREEZE. In the meantime, he relates the concepts to human behaviour too.
Then, continuing, teacher [2c_v] introduces the General Adaptation Syndrome (G.A.S.) and students have to explore the text. All other teachers act similarly.

In all classes the G.A.S. is elaborated in a class discussion, and because they give the right answers, it is concluded that students understand the stress mechanism. Furthermore, they also present examples of their own experiences with stress. Nevertheless, some remarkable quotes illustrates that the discussion about the G.A.S. is not completely clear to the teachers. Teacher [2a_v] explores the role of adrenaline in the rise and fall of the graph of the G.A.S.:

T: "How could this be explained? What could rise and decline, with the result that your welfare improves?"

S: "Adrenaline."

T: "Adrenaline, nor-adrenaline, and cortisol are hormones that are related to the regulation of the stress. (…) Those hormones ensure that you get certain levels of stress."

[2a_v, audio, lesson 3]

The last statement is not correct, because adrenaline and cortisol are a reaction to the stress level. Nevertheless, from students' answers it appears that they recognize hormones as INTERNAL STIMULI. Teacher and students [2b_h] also discuss the three phases of the G.A.S., but the teacher connects the phases with the three "F's": FLIGHT, FIGHT, and FREEZE. However, the three F's are only possible reactions to stressors in the alarm phase. Consequently, some students are getting confused:

S: "I do not know what 'resistance' is"

S: "Why does the line go down again?"

T: "In human terms one might say that someone gets overwrought."

[2b_h, audio, lesson 3]

Summarizing, the fragments presented here demonstrate that students understand the relation between stressors and behaviour. They understand that an unknown environment causes stress, and that an organism reacts according to the General Adaptation Syndrome (G.A.S.). In the self-evaluation, students indicate that they know that behaviour is caused by internal and external stimuli (havo 83%, vwo 91%). However, the recognition of the G.A.S. as a stress mechanism requires more effort from students.

Students' understanding of causation is also visible from other data, such as the workbook. Most students write a correct summary of the article in the workbook (see section 7.2, Figure 23). The following quotes of students are illustrations of a summary:

"A dog experiences stress when his environment is not predictable and manageable any more. Acute stress is not harmful, unlike chronic stress. Chronic stress can be caused by the busy society or training methods based on punishment. Dogs that are stressed may show fear-aggression. This is characterized by stress signals. A careful observer of the body language of dogs can try to give a dog more confidence in people." [2c_v, workbook, Emma & Anne]

"A dog can get stress in strange situations. If the dog is high {body language, JvM}, he is dominant. If the dog is low, he is afraid. Then you have to give him confidence. You can see many of the feelings of the dog from his body language. If a dog is acutely stressed, it can return still to its natural behaviour. In chronic stress situation it cannot and it's harmful." [2a_h, workbook, Marloes]

In the list of concepts, students described the meaning of concepts, although only students from [2b_h] have noted the concept CAUSATION. CAUSATION is than described as:

"Something that causes something." [2b_h, workbook P1, Angela],

"It makes something happens." [2b_h, workbook P1, Arina].

Students correctly understand the concepts INTERNAL AND EXTERNAL STIMULI. Most descriptions define internal and external as inside and outside (the body). Students call everything what causes stress a STRESSOR, while STRESS itself gets different descriptions. The common description is that an organism is *stressed* when the environment is not predictable or manageable anymore, or when its NATURAL BEHAVIOUR is disturbed. Nevertheless, some students formulate a definition from their own perception of STRESS, as is shown in the following quotes:

"A disturbance in the brain." [2a_h, workbook P1, Carlo]

"If you feel not comfortable, your welfare is not good at all." [2a_h, workbook P1, Geeske]

"A situation that you cannot handle anymore." [2b_h, workbook P1, Rinske]

Students distinguish between ACUTE and CHRONIC STRESS and describe CHRONIC STRESS as the phase wherein an organism is unable to return to the 'zero point'. Some students believe that CHRONIC STRESS never stops, and they understand that ADAPTATION[25] is a manner to cope with STRESSORS.

The stress mechanism can be considered as a cascade of hormones, and is therefore part of the causation of behaviour. Table 17 shows the relative frequency of the concepts that were related to the stress mechanism (see also figure 15), collected from the list of concepts in the students' workbooks.

Here, we note the following:

- Students seem to learn the concepts of the stress mechanism in the first practice and apply it in the third practice about aggression, since concepts as ALARM PHASE, FIGHT-FLIGHT-FREEZE and ACUTE STRESS are mentioned.
- The high amount of physiological concepts in the second practice is explainable, because just in that practice the molecular level is related to behaviour, and concepts as ADRENAL CORTEX, CORTISOL, ACTH, CRF are categorized as physiological concepts. The percentage of physiological concepts in the third practice is due to the high frequency that the concept ADRENALINE (14%) is mentioned, the hormone which is concerned with aggressive behaviour.

[25] Adaptation: A characteristic of an organism that makes it fit for its environment or for its particular way of life. (Adaptation, n.d.)

- Students know that the STRESS MECHANISM (General Adaptation System) consists of three phases and they indicate that in the alarm phase three kinds of behaviour could be distinguished: FIGHT, FLIGHT, and FREEZE. Furthermore, it is notable that students name FIGHT, FLIGHT and FREEZE in the third practice, because FIGHT is obviously linked to aggression.

Table 17. Relative frequency (%) of concepts related to the stress mechanism from the workbook list of concepts. Practice 1: n=387; Practice 2: n=268; Practice 3: n=49

Concept	Practice 1	Practice 2	Practice 3
General Adaptation Syndrome	1,6	1,1	0,0
Alarm phase	1,6	0,7	12,2
Stressor	15,0	6,7	10,2
Stress hormone (*)	0,3	2,6	0,0
Stress reaction/response/signal	14,0	2,2	2,0
Fight – Flight – Freeze	27,4	3,4	42,9
Acute stress	11,1	3,4	8,2
Resistance phase	1,0	0,0	0,0
overcompensation (**)	0,0	1,1	0,0
Stress level	1,6	1,1	0,0
Exhaustion phase	1,0	3,4	2,0
Chronic stress	13,4	5,6	6,1
Physiologic concepts (ACTH, Cortisol, Adrenals, Hypofyse, etc.)	12,1	68,7	16,3

(*) Only the concept STRESS HORMONE is noted; specific named hormones, as CORTISOL and ADRENALINE, are categorized under physiologic concepts.

(**) The used term is SUPER COMPENSATION, but from the given description is clear that OVERCOMPENSATION is intended.

HORMONES are the main *physiological concept* that is mentioned by students: CORTISOL, ADRENALINE, and SEROTONIN (only in the third practice). Students describe these hormones as STRESS HORMONES, or indicate where they are produced. In a few descriptions, the assumed function of hormones is indicated:

"Substance that causes stress." [2a_v, workbook P1, Paul]

"The hormone from which an animal gets stress." [2a_h, workbook P2, Wilma]

"Stress is caused by a high cortisol level." [2a_v, workbook P2, Cor]

Probably the notion STRESS HORMONE is confusing, because organisms do not get stress from cortisol. On the contrary, cortisol is released when an animal is stressed. However, there are also students who understand the correct function of cortisol:

"The substance that brings your body back into balance." [2a_h, workbook P1, Geeske]

"The de-stress hormone." [2a_v, workbook P2, Stephanie]

The same thought is expressed about the hormone serotonin. A low level of serotonin causes behaviour that is more aggressive. However, Marloes and Hanna write:

"Substance that leads to aggression." [2b_h, workbook P3, Marloes & Hanna]

Remarkable is the students' emphasis on concepts wherein social relationships play a role: SOCIALIZING, DOMINANT, SUBMISSIVE, and SOCIAL BEHAVIOUR. They also describe concepts from their own perspective instead of from the perspective of an animal. This observation is most clear for the concept of DOMINANT and SUBMISSIVE BEHAVIOUR. Students describe DOMINANT as 'being the boss' or 'feeling better than others' [2b_h, workbook P1, Janine]. SUBMISSIVE BEHAVIOUR is described as 'being humble' or 'feeling inferior', thus in affective terms. We see this in particular in the first practice about 'caring for your pet'. Obviously, students felt involved with the topic behaviour, perhaps because of its personal relevance.

The perspective of development of behaviour

The first research cycle showed that the distinction of causation from development of behaviour is difficult for students. In the second research cycle, the scenario provides for a change in perspective when the teacher leads students from studying unknown and stressful situations to studying adapted behaviour and coping with the stressors. There are two kinds of developments to be recognised: education and training. Education is addressed in LTAs[4.1] about the developmental phases of a dog, while learning processes are addressed in LTA[4.2] about training guide dogs, and assistance dogs.

Teacher and students of all classes execute most LTAs as intended. However, some remarks about the change from perspective and the reflection on the perspective can be made.

Teacher [2b_h] changes from causation to development as follows:

T: "A dog is a pet. What do you have to attain at a certain moment? Thinking of welfare, too?"

S: "Confidence. The dog has to trust you."

T: "What are you doing?"

S: "Educating."

T: "If you keep the word 'stress' in mind?"

{Students don't give answer}

T: "You teach … your dog…to cope with…?"

S: "Humans!"

T: "Stress!"

T: "That's what we get from this lesson: your dog learns to deal with some things. Are all dogs equally easy to train?" [2b_h, audio, lesson 4]

Students name age, character, race, gender, and learning method as influencing factors for learning and habituation. After the execution of the assignment about the developmental phases of a dog, the teacher [2b_h] wants to reflect on the perspective of development, but the bell rings and the lesson is over. Nevertheless, the teacher starts the new lesson with the reflection on the development of behaviour:

T: "Adaptation and learning. That is part of the previous lesson. How do dogs learn? (…) What is adaptation?"

S: "Reacting to what happens around you."

T: "Adaptation is to react? Is it reacting only?"

S: "No, you do something about it."

T: "What is the environment?"

S: "Everything around you."

T: "Development of behaviour. What do we mean with this? You talk about learning. You talk about adaptation. But, what is development of behaviour?

(…)

S "Being born, aging, learning things."

T: "Do you see a parallel with your life development? Toddler, adolescent. Also physical development of your body. That is what you see with behaviour, too. (…) because over time you develop your behaviour. You adapt your behaviour through learning things. (…)"

(…)

T: "Somebody else?"

S: "You also have to do this mentally."

T: "What do you mean?"

S: "If you have stress, you also can adapt mentally.

T: "Yes, that is an element that I did not address. You also have to be able to adapt. You not only want to adapt, but also are able to adapt."

[2b_h, audio, lesson 5]

Thereafter, teacher [2b_h] reminds the students of the stress mechanism.

The change from perspective is not always directed by a steering question, for example, teacher [2a_h] makes the following statement:

T: "We are going to look at the development of behaviour, now." [2a_h, audio, lesson 5]

After reflection on the perspective of causation, teacher [2a_v] also asks what perspective has not yet been considered. However, students do not know the answer, so the teacher gives the answer himself.

Teacher [2c_v] changes the focus from stimuli to coping, and asks students to name things that influence coping. They name environment, contact, character, and development (how a dog is treated). Then, the teacher asks:

T: "What word can you use for this?"

S: "Education."

[2c_v, audio, lesson 4]

In addition to the external influences on the development of behaviour, teacher and students explore the internal factors, such as character, race, and nature. The teacher asks:

T: "How do you name that? (…) How do you get that from your parents?"

S: "Hereditary."

T: "It is a complex interplay of internal and external stimuli."

(…)

T: "Time for a change to the next question. We have seen: education and experiences. Let's look at that: how can behaviour change? Do all dogs of all ages behave at the same manner?"

[2c_v, audio, lesson 4]

This fragment shows that the teacher tries to get the right answer, but he failed to question properly. The question how behaviour can change is ment to change from the causation to the development of behaviour, but it does not ask about the development of behaviour.

Teacher [2a_h] passes over the reflection on the developmental perspective. Furthermore, it also appeared in the classes [2a_h] and [2a_v] that the article about the developmental phases of dogs is too long, so it was made shorter for the classes [2b_h] and [2c_v].

The perspective of development was not elaborated in the other practices. Therefore, it is remarkable to see what students have written in their workbook about the development of behaviour.

In the first practice, some students described DEVELOPMENT as:

"The adaption and learning of things." [2b_h, workbook P1, Melissa]

"Progress, education." [2b_h, workbook P1, Angela]

Unlike the conception in the first research cycle, it seems that student have a correct notion of the concept DEVELOPMENT OF BEHAVIOUR.

Nevertheless, adaptation is described sometimes as HABITUATION or learning. In the third practice, adaptation is linked to group behaviour, as the following quotes illustrate:

"React at the same manner as others in the society." [2b_h, workbook P3, Carolien]

"Get tuned to a given situation." [2c_v, workbook P3, Jurriaan]

'Adapting your behaviour' seems to be subtly different from adaptation as behaviour. However, viewing the difference between practice 1 and 3, we could conclude that this difference could be related to the level of biological organisation. The first practice is at the level of the organism, while the third practice is on the level of the population. ADAPTATION then is seen as taking the others in the group into account. Students call this SOCIAL BEHAVIOUR, SOCIAL LEARNING or SOCIAL CONTROL, which is described as ‘dealing with others’, ‘taking others into account, and ‘keeping an eye on each other’.

LEARNING is only noted in the first practice, and only by five students, who described LEARNING as:

> "Unknown things that you newly discover, remember, and do." [2b_h, workbook P1, Daniëlle]

Therefore, there is no awareness of LEARNING as a process of adaptation to stressors. In the first practice students note IMPRINTING, and socializing as processes in developing behaviour, while HABITUATION is mentioned in the second practice (in particular at havo level, because of the article about the research of weaning stress of pigs). In the third practice, EDUCATION by parents is mentioned as a form of development of behaviour. "The example of parents" [2b_h, workbook P3, Marloes & Hanna] leads to learning by IMITATION.

LEARNING as a process in the development of behaviour is not often mentioned. That is understandable because in the scenario learning processes are included only in the first practice. In the second and third practice learning processes do not play a prominent role in the scenario, because the focus is on the causation of behaviour and on the physiology of the stress mechanism. It would be an option to emphasise learning processes more in the reflection phases, although it is arguable that the learning objective ‘describe the development of behaviour' could be achieved by the understanding the development of behaviour via adaptation to stimuli, both internal and external. In any case, it pleads for a clear description and explanation in the teachers' manual, so that teachers could pay special attention to learning processes in the reflection phases. Furthermore, the scenario provides too little lesson time for a more comprehensive teaching and learning about learning processes.

Summarizing, most LTAs were executed as intended, even though the reflection activities were concise. Students understand that development of behaviour is influenced by learning processes, and connected with adaptation. However, the introduction of the population level (another practice) could change the meaning of the concept DEVELOPMENT.
Therefore, it could be concluded that the LT-strategy increases students' conceptual understanding in behavioural biology, because students distinguished the three perspectives adequately. We conclude that the students' conceptual development in behavioural biology shows the required awareness of behaviour. This differs from the indications in the first research cycle. Contrary to the first research cycle, the perspective of the development of behaviour is also correctly understood, although too little time could be spent to its exploration. Furthermore, we conclude first, that teachers themselves have some difficulties with the understanding of some of the concepts, second, that they take too much time for explaining, and third, that they regularly forget to evoke motives for learning.

In addition, since the meaning of concepts is determined at least partly by the context in which they are used, a closer look at the reflection activities is required to investigate whether students reach an abstract level of understanding of the behavioural biology concepts.

9.4.2 *Reconstruction of the reflection activities*

The results of the reflection activities show what students have learned, because through reflection students have to move from the concrete level of the practice to the abstract level of the behavioural biology concepts, understanding the coherence between the concepts. In addition, adequate reflection activities should support an effective recontextualising process. In this subsection, we investigate how reflection activities are executed, and we will analyse how they add to the students' understanding of the concepts of behavioural biology. First, we consider the execution of the reflection phases in the scenario (after the first and second practice), and second, we analyse the quality of the constructed concept maps more in detail.

Although there are more informal episodes[26] of reflection-in-action during the lesson series, at the end of the first and second practice reflection activities are programmed in the scenario. In all classes, concept maps were discussed in reflection lessons. In the following reconstruction we describe how those reflection lessons proceeded. (The steps are explained in section 7.2: 1. Identify 2. Order 3. Group 4. Arrange and 5. Relate).

First reflection lesson

Class [2a_h] reflects in the sixth lesson. The teacher begins:

T: "We will start with a reflection lesson and thereafter we will pay attention to another approach of behaviour. What matters is to look at what you have learned about behaviour, and therefore you had to make a list of concepts. And we are going to put these concepts in a certain relationship."

[2a_h, audio, lesson 6]

This fragment shows the less instructive introduction of the assignment, because the terms used are rather vague (another approach, certain relationship). Nevertheless, the students deliver concepts, but the teacher, however, does not, even though not all relevant concepts are included (step 1). No ordering according to the level of abstraction is done (step 2). After that, the teacher and students classically arrange the concepts (step 3). The following fragment illustrates the teachers' approach, and the class discussion:

T: "Which of these concepts belong together? (…)"

S: "Stress belongs to acute stress and chronic stress, stress signal, stressor."

T: "What is the relationship between the...? These all are words that belong there - hey, so that grouping up a bit - I'm already connecting, that I really did not. … That all goes together. Who could explain some links between {the concepts} and explain what kind of links that gives?"

S: "There is chronic and acute stress. Chronic stress causes stress that you cannot bring back to your natural behaviour."

[26] A small adaption in the learning materials is made. In the workbook of [2c_v], after each section about a perspective on behaviour, students had to answer short questions as a summary of the section, or the summarizing instruction is marked as a summary. These episodes of reflection-in-action (Schön, 1983) are excluded in this analysis, because they are not planned in the scenario, in contrary to the reflective learning activities.

T: "Wait, natural behaviour, we also put on here."

(…)

S: "Then you indicate stress signals that you cannot return. That is because there is too much cortisol. (...) That you are going to change, so that adaptation follows. (...) And then come those three F's." {Fight, Flight, Freeze}

T: "I hear you; you can create a concept map. Very good.”

[2a_h, audio, lesson 6]

The fragment shows that the teacher chooses a rather unstructured approach to guide the process of concept mapping. Nevertheless, the students have to make the concept map for themselves (step 4 and 5). The teacher is not instructing them appropriately, so a student asks:

S: "Stress should be put in the centre?"

T: "What is the most important? What do we do?"

S: "Natural behaviour."

T: "Behaviour. That is the centre."

[2a_h, audio, lesson 6]

The teacher notices that students have problems with the construction of the concept map and starts the concept map on the blackboard (step 4). However, the teacher starts with CORTISOL, instead of BEHAVIOUR. Furthermore, the teacher uses arrows and no linking phrases (step 5). Then, the class discussion runs as follow:

T: "Where is natural behaviour related to?

S: "Welfare."

T: "What is the purpose of natural behaviour?"

S: "Survival. If you cannot, you get stress. May be acute or chronic."

(...)

T: "What causes the stress? The stressor! That is quite specific. The internal stressor is…?"

S: "Cortisol."

T: "That is the internal stimulus and you also have external stimuli.

(...)

T: "Stressor causes stress. If you have that, then there is a ...?

S: "Attack, adaptation?"

T: "Then you get a stress mechanism."

S: "Yes, that's what I mean."

T: "That stress mechanism, how is that built? You can measure that you have stress. How can you measure it?"

S: "Alarm phase."

S: "Through the cortisol."

S: "Stress mechanism, that is still in the alarm phase, adaptation phase and exhaustion?"

[2a_h, lesson 6, audio]

The fragment shows students' understanding of the stress mechanism, but because the teacher did not use a reasoning line with questioning, less guidance of the process is observed. The result of this class discussion is represented on the blackboard (figure 30).

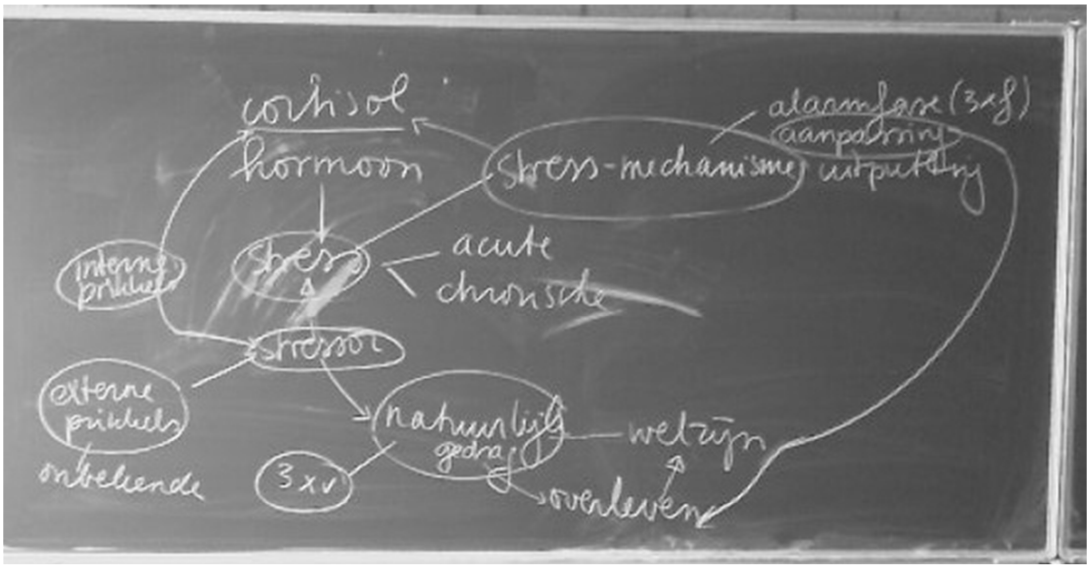

Figure 30. Overview of the 'concept map' after the class discussion [2a_h]. The concept STRESS (acute and chronic) is in the centre of the concept map, and is related to the concepts stress mechanism (including the three phases), internal and external stimuli, STRESSOR, and CORTISOL. The concept STRESSOR is related to NATURAL BEHAVIOUR, which is related to SURVIVAL, WELFARE, and the three V's: DEFENCE, REPRODUCTION, and FEEDING.

Then, the teacher abruptly changes the focus:

T: "Listen people, we're going further. We have learned about dogs and training dogs. (…) We will now make a transition to a dog that you just have as a pet, but (...)"

[2a_h, audio, lesson 6]

In addition, after some notes about assistant dogs, the teacher switches to the next practice:

T: "We switch from animals that we keep as pets to farm animals. Who can name a farm animal?"

[2a_h, audio, lesson 6]

We conclude that the above described course of the reflection lesson does not fully meet the aim of this reflection, namely to create a 'big picture' of the behavioural biology concepts. The main objection is that no perspectives are discussed, but only a part of the stress mechanism. Furthermore, it remains somewhat unclear what the teacher is attempting, and she is not succeeding in evoking a motive for reflection, or in stimulating further exploration of thoughts. In addition, in the process of concept mapping no consequent application of the rules was observed. Nevertheless, students are able to link some concepts to another, although their knowledge expression remains fragmented.

In contrast, teacher and students [2b_h] follow another approach, and the teacher explains:

T: "It addresses the question: what do we know now after four lessons about behaviour? What have you learned? What can you say about it? (...) We will try to make relations. It's like this: (...)"

[2b_h, audio, lesson 5]

Teacher gives an example of a concept: BEHAVIOUR. He discusses the distinction between concrete and abstract concepts (step 2), and clearly explains how to make a concept map, as is illustrated with the following fragment:

T: "And, if I think about behaviour, than I think directly on three things, which we see in every lesson…"

S: "Aim, development and causation."

T: "Aim, function, development and causation. What is the relation with behaviour? They are questions… Which relationship do they have to this concept {behaviour}? Possible explanations…?"

T: "In the former class someone said: 'oh, a summary'. Is that true?"

S: "No."

T: "Why not?"

S: "These are the concepts at a glance. Well, skewed by other."

S: "To relate it."

T: "Yes, and you do not that with a summary."

[2b_h, audio, lesson 5]

Therefore, it appears that students understand the three perspectives on behaviour. They also understand the aim of a concept map. The next lesson, the teacher writes the concept map on the white board (step 4 and 5), starting with behaviour and the three perspectives. All concepts are placed into the concept map, but linking phrases are not added. It is also observed a few times that students and teacher have problems with causal relations. Several students have the concept STRESS in their list (step 1), and the teacher continues:

T: "Stress. And if you think on stress, than you also think…?"

S: "Stressor."

T: "Stressor."

S: "That should be under causation?"

S: "Stress signals or something like that?"

T: "Where should it be placed?"

S: "Causation."

S: "Cortisol?"

[2b_h, audio, lesson 6]

So, CORTISOL is written on the white board (step 1).

T: "Here the question is: 'what should it be linked to?', because I have written it anywhere? One person says causation. Anyone agree?"

S: "Well, I thought Fight, Flight, and Freeze."

T: "Here is stress. That is where we begin. Well, anyway, let's go one step lower: stressor. What do you think?"

S: "Causation."

T: "Yes, the cause of behaviour. And a stressor causes stress. And stress ... Yes, what should be placed with the arrow? (...) Some said: causes of behaviour. What do you show between stress and the cause? Has anyone an idea?"

[2b_h, audio, lesson 6]

No student does answer. Students think about the concept map on the board and then, a student asks:

S: "If the stressor causes stress, then you must first indicate stressor, or stress?"

{Teacher has pointed to the board: source → stress → stressor, JvM}

S: "Yes, but stress is the cause of the behaviour."

S: "But then is cortisol first? That is the stress hormone."

S: "Then there is something you get stress from."

S: "So?"

T: "Yes, but, stressor. And then a step higher you have your stress level?"

S: "But it's not "leads to?" You say that stressor leads to stress."

T: "Yeah, how do you rename?"

S: "Then the arrow should be signed the other way. Well, never mind."

S: "Yeah, cause comes first, then stressor, then stress."

S: "Yes, but then behaviour should also be down."

S: "You should start something as the least and then it becomes increasingly larger."

T: "What is a stressor?"

S: "That what you get stressed."

T: "Something you get stressed. So, in that sense than stress get a step up. Stress is a cause, or one of the causes of behaviour; it leads to certain behaviour."

[2b_h, audio, lesson 6]

Finally, the teacher concludes, asking:

T: "Do you see that all those single elements (…) have coherence?"

[2b_h, audio, lesson 6]

From these fragments, it appears that this teacher knows where to go, and that the process of concept mapping is more difficult than was expected. Furthermore, students and teacher have difficulties with causal relations. However, teacher and students are fully focused on combining the concepts in the concept map, because they understand that this form of reflection gives them a big picture of behaviour. After finishing the reflection, the teacher changes the practice, and asks:

T: Does this picture also work for farm animals? [2b_h, audio, lesson 6]

Therefore, the motive to change from the second practice is delivered by the teacher. The students' opinions are divided: ‘Cows are not going to fight or flight’; but most of the students agree that the concepts could be used as well for explaining behaviour of farm animals. It seems to be a correct change of the practice, and students' attention is focused on farm animals.

Class [2a_v] starts the reflection lesson with comparing the concept maps they made at home (step 1), although half of the students did not accomplish the assignment. Therefore, it was decided to make the concept map centrally with the help of the software program Cmaptools and the projector (figure 31).

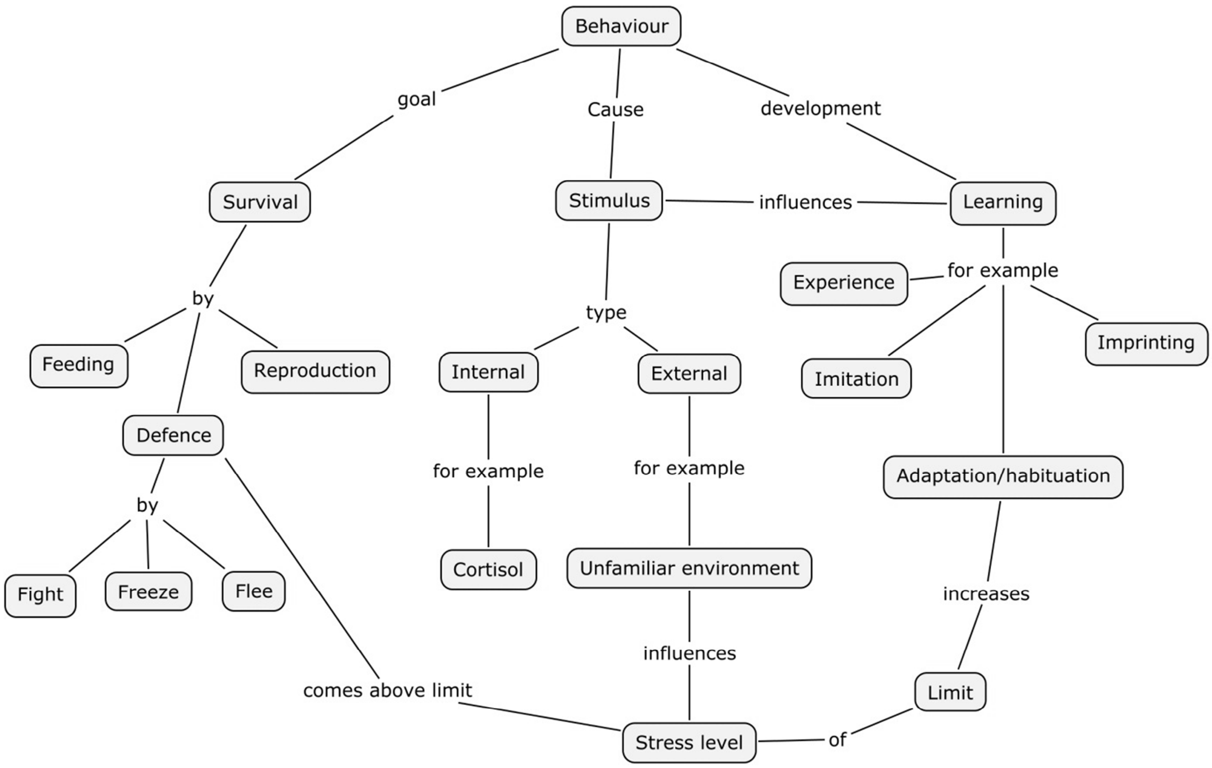

Figure 31. Concept map made in class discussion [2a_v].

First, the teacher indicates the difficulty of the distinction between a concrete or abstract concept (step 2), but does not explain the difference between concrete and abstract, as the following quote illustrates:

T: "Put in an abstract or concrete box, that's very difficult. What is concrete and what is abstract? Where do you draw the line? Let's just start very abstract. The chapter is about …? And let us write that on top, and let us try to go down to see if we can make that more concrete. (...)"

[2a_v, audio, lesson 6]

Later on, the teacher explains from the concept map (step 4):

T: "You see now, we started with behaviour. We made it more concrete by going to 'survive' (…), thus we are going to be more concrete."

[2a_v, audio, lesson 6]

From this fragment, it appears that the teacher uses abstract/concrete as a continuum. However, more or less concrete does not exist.

Next, in figure 31 the three perspectives are written as linking phrases, so a proposition is not correctly elaborated. However, the teacher leads the students' thinking through the concepts of behavioural biology, following the structure of the three perspectives (step 3, 4). The following fragment illustrates how the discussion is steered by the teacher:

T: "We have seen that behaviour could be viewed from three perspectives Joost, I almost dare not ask you, but perspective number 1 is?"

S: "Eh, survival."

T: "Now a perspective. This is almost there. I am going to write the word 'survival' down here, but I want to know what they have to do with each other."

S: "The aim!"

T: "Exactly. 'Survive' would be generally named the aim. Then there were two other things we would watch. Besides aim, we distinguish also?"

S: "Development!"

T: "And the third one?"

S: "Causation."

T: "Yes, exactly. (…) And what do you generally say about causes? What is now leading to behaviour? (…)"

S: "That species can collaborate?"

T: "Yes, but that is an aim; that is more than an aim. But what leads to that, at the time I throw this book at your head and you throw a bag back at me? What have you got for me?

S: "A reason."

S: "A bag."

T: "Yes, exactly. Actually, it is a book. Or you get receive some light, or you receive some sound, or you take in what in general?"

S: "Stimuli!"

(…)

T: "Survive..., how do you do that?"

S: "By eating."

T: "Yes, the V of …?"

[2a_v, lesson 6, audio]

This fragment shows that students are able to reproduce the three ‘V's’ (FEEDING, REPRODUCTION, and DEFENCE), and they reproduce most in time the correct concepts (step 1). However, the teacher also uses answers that are not correct at that time, and indicates relations between concepts when possible. In addition, concepts of the development of behaviour are remembered by students, as illustrated by the following fragment:

T: "Developing is going through…?"

S: "Grow up."

S: "Evolution."

T: "Yes, that is correct. And what do you do in education?"

S: "Learning"

[2a_v, audio, lesson 6]

Teacher [2a_v] also indicates cross-links between the three perspectives (step 5). When talking about the development of behaviour the teacher concludes that parents have influence on the learning process of their children, in other words, they stimulate learning, and he draws a line from stimulus to learning, as is shown in figure 32.

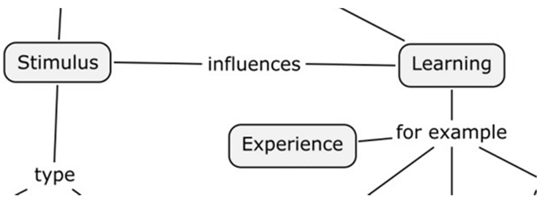

Figure 32. Part of the concept map [2a_v] of figure 31, showing cross-links between the perspectives of development and causation of behaviour.

Another example of cross-linking is the relationship between ADAPTATION, STRESS LEVEL and DEFENCE, as is shown in figure 33. The instructional conversation below shows that the causal perspective is related to the perspective of function:

T: "And now, we come to the following: if this {stress level} is above the limit, what happens then?"

S: "Then you get chronic stress."

S: "Then their behaviour is going to change."

T: "Yes, what are you going to do? For example?"

S: "Aggression"

T: "Yes, for example. You can go to this: stress level. But then you can relate to each other so here."

(…)

S: "You also could name it defence."

T: "Yes, I agree, thus if you have not linked it…"

S: "You are not just fighting?"

[2a_v, audio, lesson 6]

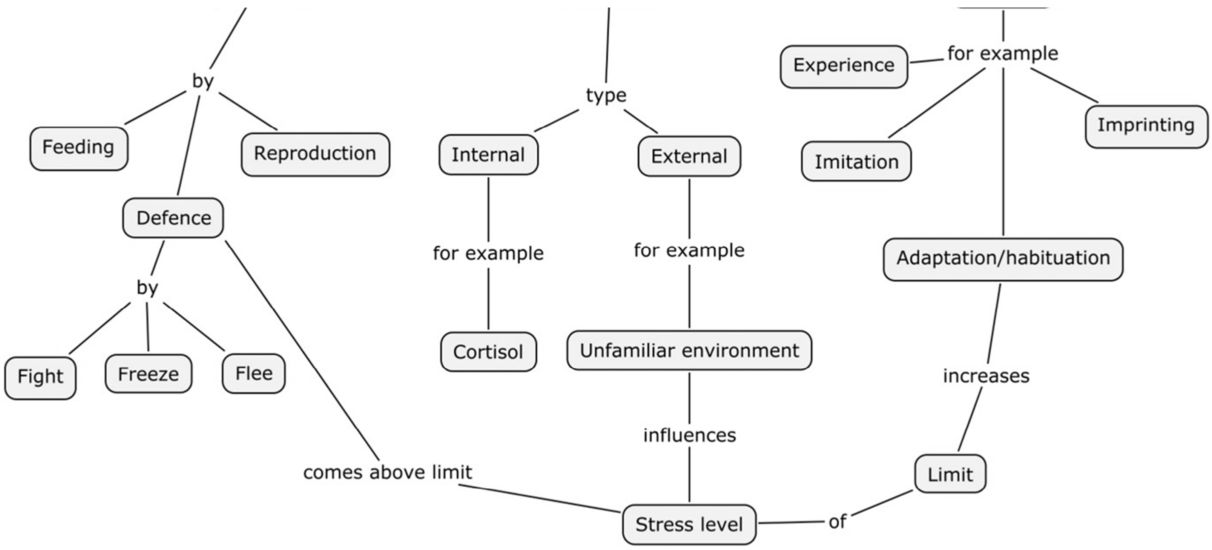

Figure 33. Part of the concept map [2a_v] of figure 31, indicating cross-links between the three perspectives of behaviour.

Contrary to class [2b_h], it appears that students [2a_v] do not have problems with causal relations, probably inherent to their pre-university level.

Then, the teacher [2a_v] repeats the entire figure again as a summary, followed by the change of the practice. For that, the teacher uses students' own stress level by asking some students to sing the anthem. Nobody is willing, because students find it embarrassing. This seems to be a fluent change to the next practice, because students were focused on the concept STRESS and got involved in their own experience. Therefore, the motive for exploring a new practice is not related to a concept (BEHAVIOUR), but has a personal relevance with its relation to the concept STRESS.

The instructional dialogue with teacher and students [2c_v] shows similar experiences to the other group at vwo level ([2a_v]). Students have to list the concepts in duos, and after ten minutes, the list is presented at the blackboard. It shows that concepts as CAUSATION, DEVELOPMENT and the trio FEEDING, REPRODUCTION, and DEFENCE are missing (step 1).

Furthermore, it is noticed how students describe what the meaning of ‘abstract’ and ‘concrete’ is. Concrete is described as tangible, while abstract is described in term of what it is not. Students describe concrete as ‘important’, and abstract as ‘background’ (step 2).
The teacher explains the procedure of concept mapping, and emphasises that the action of creating a concept map is more important than the product, because during creation the thinking process is active. The teacher explains that it is interesting both that the concepts are related to each other, and how they are related (step 5).

Unfortunately, because of a misunderstanding in vacation planning, no audio recording is available from the reflection lesson [2c_v]. However, the report of the teacher about the lesson course reveals similar observations as in [2a_v]: short lists of concepts and difficulties in creating propositions (step 1 and 5):

> "I have looked to the concept maps of the students and observed that most of them had a simple concept map consisting of about six concepts and little linking phrases.
>
> [2c_v, audio, teacher after lesson 6]

According to the teacher, students report hesitations over which concepts they should include (step 1). One student said that if she would link all concepts to each other, it would become a mess. Therefore, the question is which concept has to be linked to another. The teacher said he sometimes has the same problem when he is creating a concept map. Furthermore, it was observed that students do not use all the concepts they identified, because they feel uncertain about the correctness of the concept map. Therefore, the teacher emphasised that the process of concept mapping is more important than the product. He built a concept map during the lesson, and students pointed out that the teacher had forgotten the concept WELFARE, which illustrates that students probably have an appropriate understanding of the behavioural biology concepts (step 1).

The change of the practice is again as intended ([2c_v]). It appears again that students easily tend to relate the concept STRESS with their own experiences.

Second reflection lesson
After the second practice a second reflection lesson was programmed, wherein a concept map of the second practice is constructed. Although, this reflection lesson is executed adequately in most classes, some issues require discussion.

Students [2a_h] did not reflect in the form of an instructional dialogue, because of a lack of time. Students get the assignment to compare the concept map that they made after the first practice with the map from the second practice, and to look if there are any new concepts. However, most of the students copy the former concept map. Students [2b_h] have to construct a concept map in the reflection lesson, but at the end of the school year students' activity is not very high. However, it also could be that the assignment of concept mapping needs more structure, so that students have more guidance in constructing a concept map. A short fragment of the dialogue between two students shows that students are not reasoning very precisely.

S1: "First welfare, then freeze."

S2: "Then, we also have here."

S1: "That is never!"

S2: "I put it down here. Draw arrows."

S1: "Freeze, and then this works."

S2: "And then you get down defence; movement and defence. Right?"

S1: "Yes, then cortisol works."

S2: "So after cortisol comes?"

S1: "Defence, and movement by defence."

[2b_h, audio group b, lesson 9]

The results of this confusing dialogue are shown in figure 34. Does this student sufficiently know how to create a concept map?

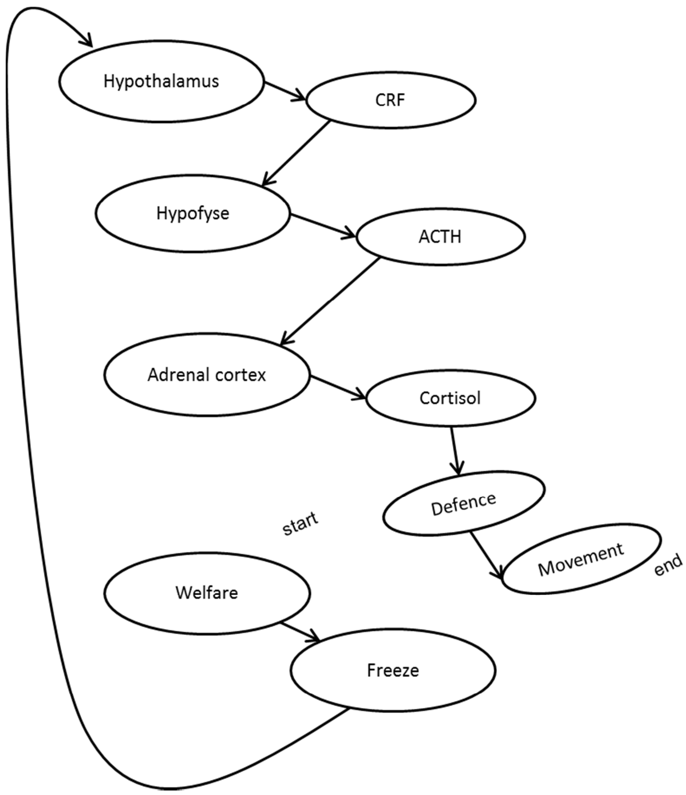

Figure 34. Students' concept map of the second practice [2b_h, workbook, Melissa]

In addition, another couple of students have a more logical dialogue that run as follows:

S1: "What topic do we tackle?"

S2: "I think stress or something? That's a bit of his story."

S1: "And then you have chronic and acute stress."

S2: "And I understand it no longer."

S1: "I also think the environment? Because if you sit in a corner you have more stress."

S2: "Chronic stress: you have no good welfare."

S1: "And …, natural behaviour. They cannot do more."

S2: "Acute stress is adaptation, I think."

[2b_h, audio group e, lesson 9]

Their concept map is limited, and deals only with STRESS and included no propositions, as is shown in figure 35.

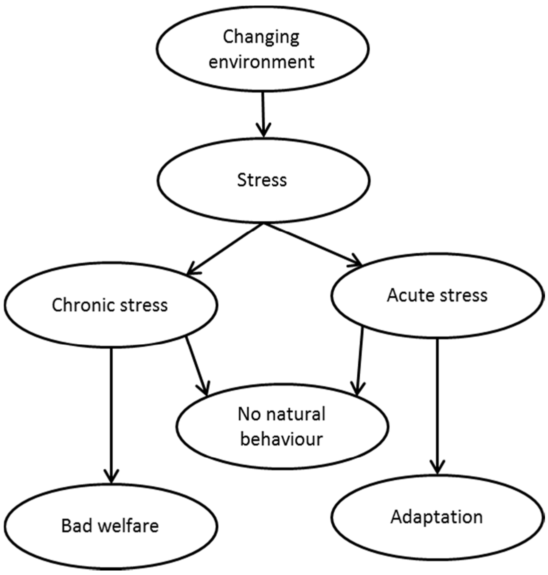

Figure 35. Students' concept map of the second practice [2b_h, workbook, Marinka]

Nevertheless, when the researcher asks the students to think about their concept map, they give the correct answers. The next part of this dialogue shows that students are able to explain their concept map:

R[27]: "Where is behaviour written {in your concept map, JvM}?"

S: "Not here in between."

R: "Why not?"

S: "Yes, that's a good question!"

(…)

R: "What does that have to do with stress? Because you choose ‘stress' as the main concept. That is possible. What kind of stress? Who? With what?"

S: "With animals."

R: "Yes, what kind of animals?"

S: "Farm animals."

[27] R = Researcher

(…)

R: "What kind of stress did the pigs have?"

S: "They were in a small room."

R: "Yes, and in particular we looked at some research …"

S: "Yes, about the free space. That it makes a difference if they are away from their mother to the great stable."

R: "Yes, exactly. How is that named?"

S: "To wean."

R: "Yes, and that seems to cause stress. Why did you note 'environment' here?"

S: "Well, that has to do with it. If you live in a small cage, you have more stress than when you have more space."

R: "Yes, thus you could say: the environment has influence on stress. (…) When causes the environment stress? What happened with weaning?"

S: "Because there things were changed."

R: "(…) a change of environment causes stress. How did the pig learn to adapt?"

S: "Adaptation."

R: "Yes, but how?"

S: "Well, by first getting used to a larger space."

R: "Yes, what is that called?

S1: "I don't know."

S2: "Habituation."

R: "Yes, and if you learn something, does that belong to the function, causation or development of behaviour?"

S: "Development."

[2b_h, audio group e, lesson 9]

Therefore, the above-mentioned fragment shows that students are supported by their own concept map. However, more guidance in the designing of, or discussing, a concept map may result in a better understanding of the relationship between concepts.

In the 10th lesson teacher [2b_h] discusses a concept map of the researcher (Appendix D) with the students, and the researcher advises using this concept map in the last practice. The dialogue fragments, reported by teacher [2c_v] show similar experiences with the first reflection lesson, namely that students write a list of concepts, but do not use all these concepts in a concept map. So, it seems that concept mapping requires a more guided approach, in particular in the havo classes.

Students in the vwo classes also reflect on the second practice. Working in duos, students [2a_v] construct the concept map, discussing the concepts to be used. It appears that also these students have difficulties in starting with the concept map, as is illustrated with the following fragment.

S1: "Should {this concept map, JvM} not meant to be incorporated in the previous concept map?"

S2: "That you add actually a bit?"

T: "That's not a bad plan!"

S1: "We know where to start."

[2a_v, audio group 1, lesson 11]

Then, a short discussion about the approach followed: should we add concepts or first make a list of concepts? From the audio fragments, we observed that vwo students show more reasoning than havo students. For example, the following part of the dialogue:

S1: "Behavioural changes due to training. They are due to a high cortisol level. What causes chronic stress, which ultimately leads to burnout?"

S2: "Yes, but can you still say that overtraining is measured by the cortisol levels?"

S3: "No, chronic stress is measured, not training."

[2a_v, lesson 11, audio group 2]

Other students were asked about the differences between the concept maps after the first and the second practice. The question shows that these students have an understanding of the several appearances of stress and its relationship with behaviour, as appears from the following dialogue between students and the researcher:

R: "If you look at the previous concept map of the dog. What is noteworthy then?"

S: "Well, here the most {concepts, JvM} are sequential. With the {concept map of the, JvM} dog there were more side branches."

R: "More branches?"

S: "Yes, but the stress level is also in here, but we are looking in a different way."

R: "Yes, how?"

S: "Well, here we looked at what your body is doing and with horses we looked more to what it does to you mentally, with the inside of your body. And with the dog it dealt what the response was outside {the body, JvM}."

R: "Okay. Under what question did we align that? What title?"

S: "Survival."

R: "Yes, and beyond?"

S: "The behaviour."

[2a_v, audio group 3, lesson 11]

We conclude that adequate reflection time was programmed in the second research cycle, and it seems that students' conceptual development was stimulated by reflection through the construction of concept maps. In addition, the reflection phases provide for a possibility to change the practice by evoking a new motive or steering question.
Furthermore, some students and teachers wonder what the difference is between concept mapping and mind mapping, which indicates that the aim of concept mapping is not completely understood. In the havo classes, the assignment of concept mapping is too open, so more guidance is needed. It is observed that the havo students have more difficulties with causal explanations than the vwo students. Vwo students also have difficulties starting the concept map and deciding which concepts should be included.
Therefore, it is questionable which skills are necessary for this form of reflection. In particular, two skills are required, namely the making of concept maps and thinking about behaviour, which seems to be difficult for students without experiences with concept mapping. The 5-step instruction for constructing a concept map should be more detailed and pre-programmed.

9.4.3 *Concept maps as a tool for conceptual development*

In the previous section we reviewed the reflection process and concluded that students' conceptual development was stimulated through the construction of concept maps. Nevertheless, we concluded that the 5-step-instruction to construct concept maps seems somewhat problematical. Therefore, the question is how is the quality of the constructed concept maps? In addition, since many concept maps are constructed as a homework assignment, and thus are not included in the review of the reflection process as described in the previous section. In this subsection, we take a closer look at the quality of the produced concept maps of students as the results of the reflection.

First, we consider the technical quality: are the concept maps constructed as intended. Second, we investigate the domain-specific quality and review the used propositions more in detail to understand the contribution of concept maps to the students' conceptual development.

In totally 112 concept maps constructed by students after the first and second practice are available (see table 18). Some students collaborated in the concept map construction, while others declined to construct a concept map.

Table 18. Number of students' concept maps after the first and the second practice, both at havo and vwo level.

	1st practice	2nd practice
Havo	30	34
Vwo	28	20

Analysis of the technical quality of the students' concept maps

It appears that 27% of the students' concept maps include linking phrases. With one exception, all these concept maps are constructed by students at vwo level. It is observed that concept maps show big differences in the number of concepts and in structuring. Most students did not use arrows in their concept maps. Most concept maps lack cross-links, which could be considered as an option for an expert. Students should be considered as novices in concept map construction.

Domain-specific quality of the students' concept maps

The above-mentioned technical analysis of the concept maps concerns only about 25% of the concept maps, and in particular, only some of the concept maps at vwo level are technical correct. However, since this chapter focus on students' conceptual development the question is what all concept maps reveal about students' conceptual understanding. Therefore, the domain-specific quality of the concept maps is evaluated. As we described in section 7.2, all propositions in the concept maps of the first and second practice are analysed in order to investigate the students' understanding of the behavioural biology concepts.

Totally 1591 propositions were classified, and table 19 shows the relative distribution for the three fore-mentioned classes. It appears that 87% of the students' propositions are more or less correct, although no linking phrase is used. Furthermore, from table 20 it appears that students are able to make more or less correct propositions, even when they construct the concept map technically incorrectly.

Table 19. Relative distribution of the students' propositions (n=1591) for the three categories: 1. Proposition is correct. 2. Two concepts correctly linked. 3. Proposition is incorrect.

	Category 1	Category 2	Category 3
Relative amount of propositions	44%	43%	13%

Table 20 shows the relative distribution of the propositions, classified by the technical quality of the concept map and the evaluation whether a proposition is conceptually correct or not. From this table, we could conclude that technically incorrect concept maps could contain conceptually correct propositions.

Table 20. Relative distribution of the students propositions (n=1591) of concept maps (n=112). The propositions are classified by the technical quality of the concept maps and judged whether a proposition is conceptually correct.

	Technically incorrect concept map	Technically correct concept map
Correct proposition	50	37
Incorrect proposition	5	8

The domain-specific quality of all concept maps is considered by the analysis of all propositions. Table 21 shows the list of basic propositions with the classifying concept. For each basic proposition, represented by its classifying concept, three ratios are shown. For example, for the first proposition, 3.2% of the propositions in students' concept maps can be classified with the concept BEHAVIOUR. From this amount 71% of the propositions are correctly noted by students. Finally, the proposition occurs in 46% of the students' concept maps.

It appears that 68.2% of the propositions could be related to a behavioural biology concept (classifying concept 1-20), and 14.6% of the propositions could be related to the physiology of the stress mechanism (classifying concept 21), and 17.2% of the propositions are context-related (classifying concept 22-24).

Table 21. List of propositions, based on the basic concept map (figure 15), and the concept that classifies a proposition. Relative distribution of the classified propositions (n=1591), collected from students' concept maps (n=112). A = relative distribution (%) of total propositions; B = relative amount (%) of correct (linked) propositions [category 1 and 2] belonging to the classifying concept; C = ratio correct propositions / total number of concepts.

	Proposition	Classifying concept	A	B	C
1	Organisms *have* (natural) Behaviour	Behaviour	3.2	71	0.46
2	Welfare *of an* organism *is defined as its* physical health and mental health	Welfare	2.4	66	0.34
3	(natural) Behaviour *is explained by its* Function	Function	3.3	83	0.46
4	(natural) Behaviour *is explained by its* Causation	Causation	2.3	92	0.32
5a	(natural) Behaviour *is explained by its* Development	Development	1.4	96	0.21
5b	Development *is introduced by* learning processes				
6	Function *which aims to* survive	Survival	2.8	98	0.39
7	Survival *by* Reproduction, Feeding, and Defence	Reproduction, Feeding, and Defence	1.1	78	0.16
8	Defence *by* Fight, Flight, and Freeze	Fight, Flight, Freeze	4.2	81	0.60
9a	Causation *by* internal and external factors	Internal and external stimuli	6.8	95	0.97
9b	Internal factors *e.g.* genes, and hormones				
10	Internal and external factors *also called* stressors	Stressor	5.8	90	0.82
10a	Stressors *cause* stress reaction				
11	Stress reaction *to distinguish in* acute and chronic (stress) route	Stress reaction	10.6	85	1.50
12	Acute stress *is showed by* Flight, Fight, and Freeze	Acute stress	4.6	96	0.65
13	Chronic stress *leads to the* Resistance and Exhaustion phase	Chronic stress	5.8	90	0.83
14a	Stress reaction *which is described by the* General Adaptation Syndrome	Stress mechanism (G.A.S.)	2.8	98	0.39

14b	General Adaptation Syndrome *divided into the* 1) Alarm phase. 2) Resistance phase. 3) Exhaustion phase.				
15	Flight, Fight, and Freeze *are possible reactions in the* Alarm phase	Alarm phase	0.5	100	0.07
16	Adaptation *takes place in the* Resistance phase	Resistance phase	0.1	100	0.02
17	Exhaustion phase *leads to* death	Exhaustion phase	0.2	100	0.03
18a	Learning processes *such as* habituation, imprinting, playing, and conditioning	Learning processes	1.1	100	0.15
18b	Habituation *provides for* adaptation				
18c	Conditioning *for* a task				
18d	Learning processes *to* a task, and maturity				
19	Stress reaction *leads to* adaptation	Adaptation	2.5	72	0.36
20	Propositions due to the concept natural behaviour	Natural behaviour	7.1	87	1.01
21	Propositions due to the physiology of the stress mechanism	Physiology	14.4	83	2.04
22	Propositions due to the practice of the dog	Dog	12.2	90	1.74
23	Propositions due to the practice of overtraining	Overtraining	3.8	80	0.54
24	Propositions due to the practice of farm animals	Farm	1.1	100	0.15

From table 21 can be concluded that minimally half of the concept maps (column C > 0.50) include propositions belonging to the perspective of causation and to the concepts of the stress mechanism (propositions 8-13, 21). At the other hand, students did elaborate the phases of the stress mechanism to a limited extend (propositions 14-17, 19).
Furthermore, considering the high amounts of correct propositions (column B), it appears that less concept maps include incorrect propositions. That means that the domain-specific quality of the concept maps is high.

We consider the classifying concepts with less than 80% correct propositions (1, 2, 7, and 19). Students seem to have difficulties with the propositions belonging to the classifying concepts BEHAVIOUR (proposition 1, 71%) and WELFARE (proposition 2, 66%). The proposition *'Organism has (natural) behaviour'* is indicated by only a few students, while others understand that BEHAVIOUR is related to WELFARE. Students relate BEHAVIOUR to NATURAL BEHAVIOUR, and state that behaviour is caused by STIMULI, or that behaviour is changed when the environment changes. Some incorrect propositions pass over steps. For example, in the proposition *'Behaviour, such as fight, flight, freeze'* the concepts FUNCTION – SURVIVAL – DEFENCE, are passed over. Another student noted that *'behaviour influences natural behaviour'*, which is impossible.
The welfare of an organism is defined as physical and mental health, and it appears that 34% of the propositions dealing with welfare (classifying concept 2) are incorrect. Incorrect propositions relate WELFARE to ADAPTATION, examples of behaviour (e.g. freeze), or change cause-consequence (*'welfare influences natural behaviour'*, *'welfare causes behaviour'*).

Furthermore, students seem to have difficulties with the relationship between SURVIVAL and DEFENCE (proposition 7, 22% incorrect propositions). However, only 1.1% of the propositions are classified with concept 7, and consequently the incorrect propositions are less than 1% of the total amount of propositions. From the behaviour systems FEEDING, REPRODUCTION, and DEFENCE, defensive behaviour is mostly noted, which could be declared because it is the concept that is elaborated in proposition 8.
The relation between STRESS and ADAPTATION is incorrect in 28% of the propositions (proposition 19). The concept ADAPTATION is placed in the resistance phase of the G.A.S.. Students link ADAPTATION to WELFARE, SURVIVAL, and STRESS(OR), although not always correctly. For example, students think that ADAPTATION causes STRESS, or even the STRESS MECHANISM.

Furthermore, we observed that the students' concepts maps show a large diversity in the included propositions. A single concept map contains an average of 14 propositions (standard deviation = 7.3), which is 59% of the classified concepts.

Table 22. Qualification of the domain-specific quality of students' concept maps (n=112), distributed to a range of the ratio of used propositions/amount of classified concepts (n=24).

Ratio: used propositions/24	Relative distribution (%) of the concept maps	Relative distribution (%) of the propositions (n=1591)	Average percentage correct propositions
0-0.2	8	2	79
0.3-0.5	46	33	83
0.6-0.8	32	38	89
0.9-1.2	10	16	88
1.3-1.7	4	12	92

Table 22 shows that nearly half of the students (46%) constructed a concept map that covers more than 60% of the classifying concepts (ratio 0.6-1.7). Nevertheless, also students who constructed a concept map with fewer propositions constructed merely correct propositions. Furthermore, it appears that the higher ratio a concept map has, the higher the amount of correct propositions, and consequently the higher the domain-specific quality of a concept map it appears that students who constructed a high rated concept map.
In addition, as we described in section 7.2, the domain-specific quality of the technically correct concept maps is also investigated by the use of the propositions distinguished by the types of relationships. The results for the following analysis of the concept maps on the relation types are based on a set of 31 technically correct concept maps, 12 concept maps about the first practice, and 19 about the second practice. Figure 36 shows the relative distribution of the relation types that are used by students in the linking phrases; the differences between the first and second practice are remarkable. In short, we could say that the causal and functional relation types indicate for explanation, while the part/whole and example relation type are descriptive. In the first practice, students have learnt the structure of behavioural biology, while in the second practice attention is paid to the working of the stress mechanism. Therefore, in the first practice, it is understandable that the emphasis is on the relation type part/whole and examples, and in the second practice on the causal and functional relation types.

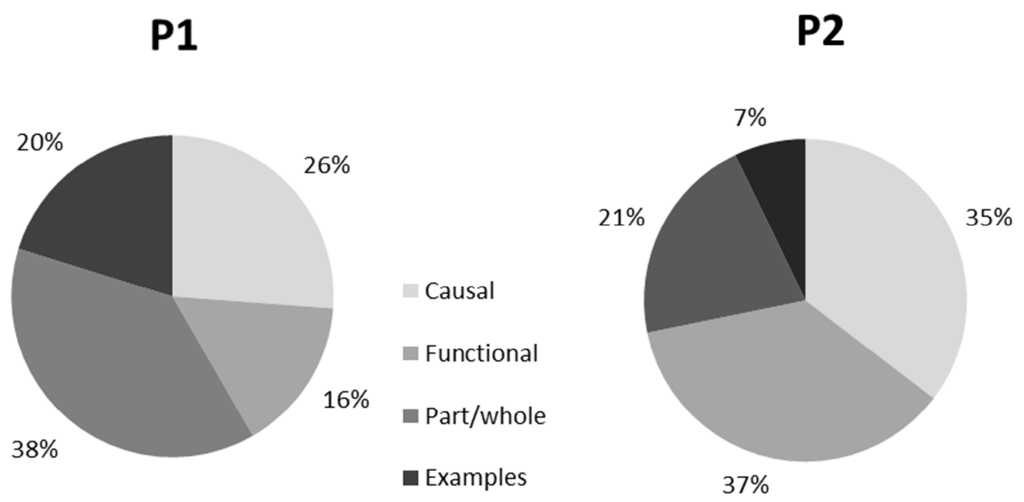

Figure 36. Relative distribution of the relation types used in the linking phrases of the propositions in the concept maps of the first (P1) and the second practice (P2).

As an example in figure 37 and figure 38 the propositions are indicated. In figure 37 the emphasis is on the relation type part/whole, and some examples illustrate this type of proposition (cursive words are the concepts):

P0 *Dog* can be *trained*

P3 *Dog* lives in a *pack*

P4 *Survive* through *reproduction*, *defence*, and *food*.

[2a_v, P1, Kaj]

Other relation types are recognized with the following propositions:

F1 *Dog* has to *survive*.

C1 *Stress* causes *aggression*

C2 *Stress* is caused by a *stressor*

E2 *Stressor*, e.g. *unfamiliar environment*

[2a_v, P1, Kaj]

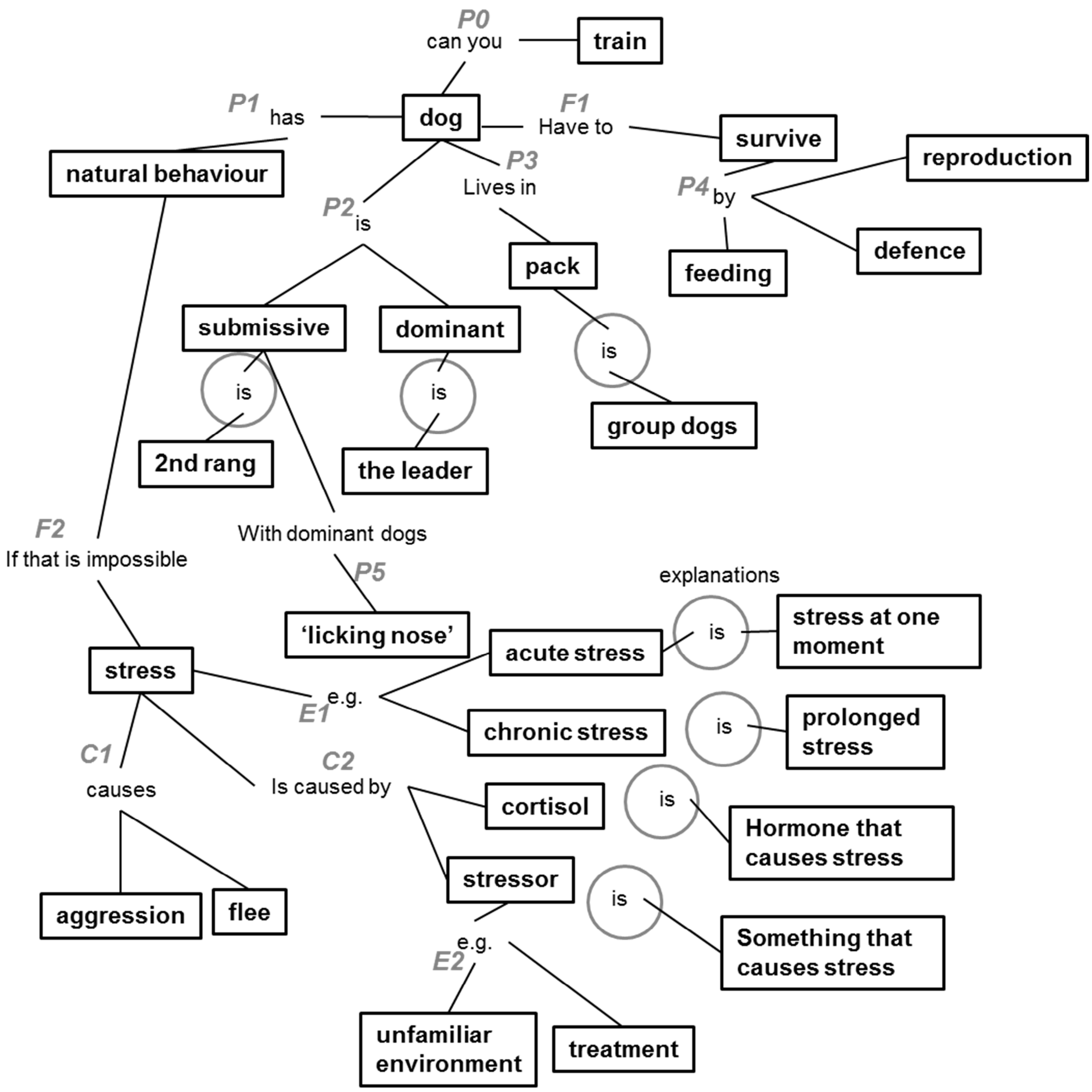

Figure 37. Concept map of [2a_v, P1, Kaj] wherein the type of propositions is indicated. C = causal relation type; F = functional relation type; P = part/whole relation type, and E = example relation type. The circle indicated for a proposition that is an explanation.

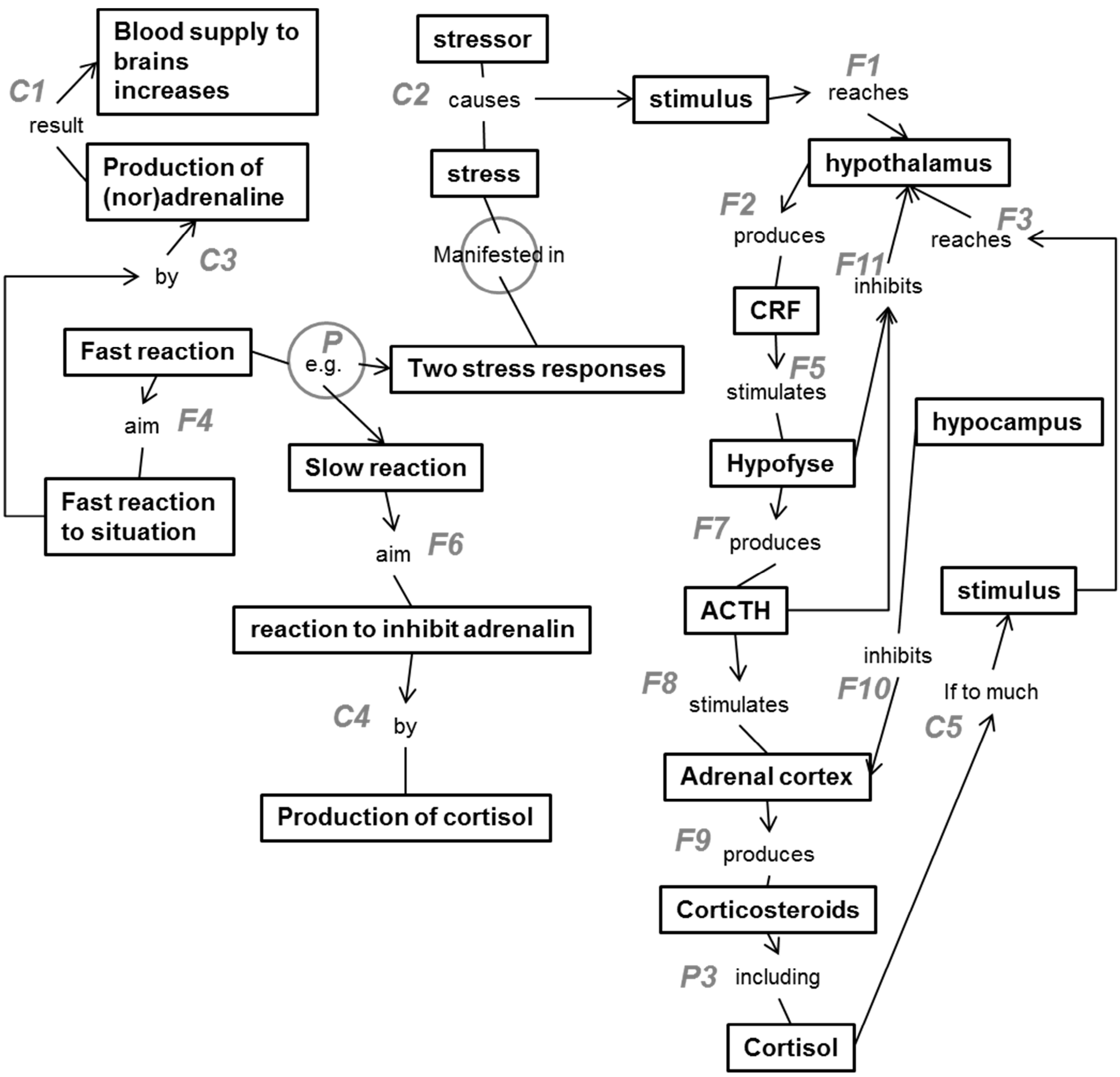

Figure 38. Concept map of [2a_v, P2, Jolenthe], wherein the type of propositions is indicated. C = causal relation type; F = functional relation type; P = part/whole relation type, and E = example relation type. The circle indicated for a proposition that is an explanation.

The next concept map, figure 38, is a reflection on the second practice, wherein the physiological working of the stress mechanism is elaborated. Therefore, the functional relation type is dominantly present, while the causal relation type is also indicated. The next propositions illustrated these types:

C2 stressor causes stress

C4 to inhibit the violent working of adrenalin by production cortisol

F6 slow response {to stress, JvM} aimed to inhibit the violent working of adrenalin

F7 Hypofyse produces ACTH

F9 ACTH stimulates the cortex of suprarenal gland

[2a_v, P2, Jolenthe]

Finally, (technically correct) concept maps of both the first practice and second practice are available from only a few students. It appears that the concept maps of the second practice stand alone, and are not constructed with the concept map of the first practice as a basis. That suggests that students reflect on the practice, instead of on the behavioural biology concepts. Figure 39 is an illustration of the concept maps of the first and second practice of one student. While the concepts of the map of the first practice are grouped by the concept STRESS, in the second concept map OVERTRAINING is elaborated as the central concept. Furthermore, it shows that in the concept map of the second practice is more comprehensive, but with concepts due to the second practice. In addition, each concept map has a different design.

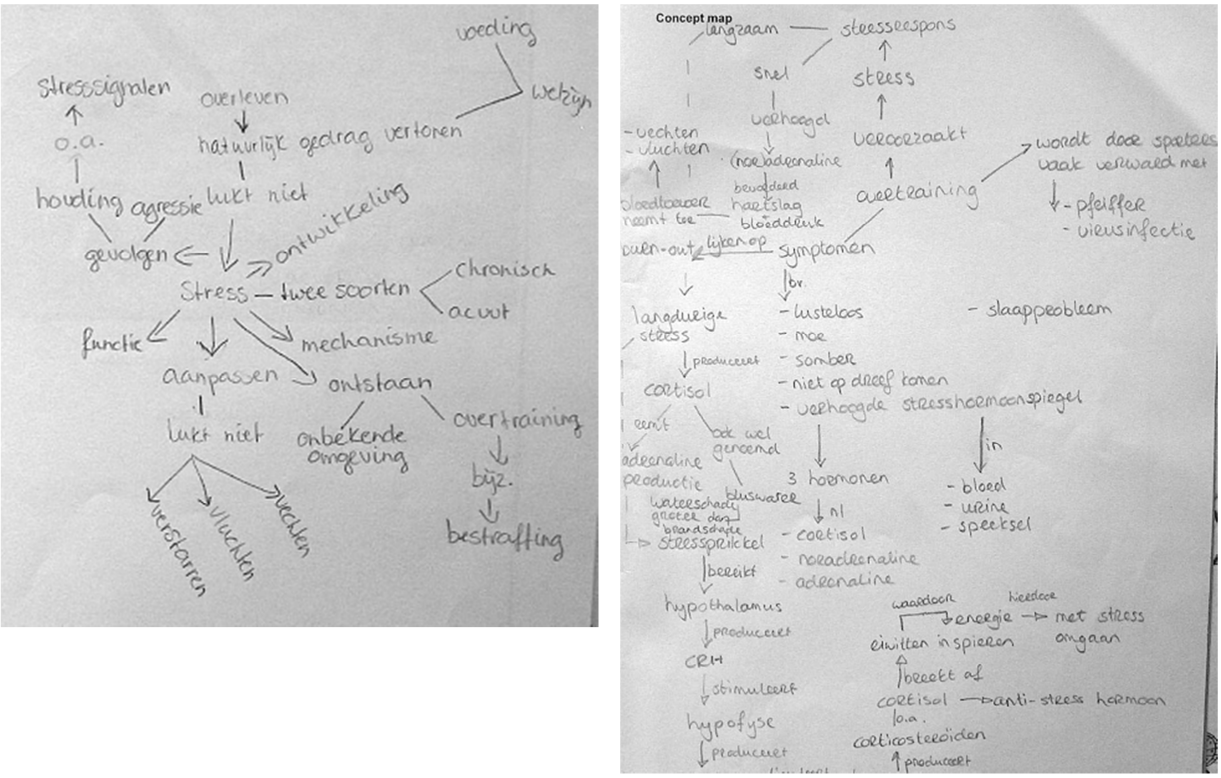

Figure 39. Concept maps of the first practice (left) and the second practice (right) of Annelot, [2a_v, P1/P2, Annelot]. Both concept maps differ in the central topic (left: stress; right: overtraining), and in structure.

In sum, the technical quality of a concept map could be determined by the use of correct propositions, including linking phrases. It appears that only approximately 27% of the students’ concept maps meet the criterion of having linking phrases. The students’ concept maps show big differences in the number of concepts and in structuring, with no use of arrows and lacking cross-links. Students should be considered as novices in concept map construction. In general, we could conclude that the technical quality of the students’ concept maps remains weak, and it is supposed that the weak quality of the concept maps is caused by a lack of experience in concept mapping by teacher and students. Therefore, adequate preparation is necessary, including for the teacher. It could be supposed that increasing the technical quality of concept maps also further increases the students' conceptualization. We found that because of a missing linking phrase an incorrect proposition could be multi-interpretable, and that students leave out some concepts between the indicated concepts. In addition, students use concepts from outside behavioural biology, and the lesson series, or 'translate' behavioural biology concepts in their own words. Nevertheless, considering the domain-specific quality of the concept maps, it appears that students are able to relate the concepts correctly. Therefore, analysing the technical quality of concept maps has limited value, and is not a sufficient measurement for conceptualization of behavioural biology concepts by students.

The concept maps show a large diversity in the number of propositions and the individual student elaborated an average of 59% of the classifying concepts in a concept map. Nevertheless, also students who constructed a concept map with fewer propositions constructed merely correct propositions. Furthermore, the analysis of the domain-specific quality of concept maps shows that students have a satisfactory understanding of the behavioural biology concepts, in particular STRESS and the STRESS MECHANISM. For most classifying concepts the amount of correct propositions is above the 80%, which is high.

Students use different concepts as starting point of the concept map: BEHAVIOUR, OVERTRAINING, STRESS, and WELFARE. The differences between the technically correct concept maps of the first and second practice are merely context bound. It appears that students, who constructed a technical correct concept map, used different relation types. However, the used relation types depend on the character of a practice: is it descriptive (first practice) or is the functioning of the stress mechanism elaborated (second practice). It seems that students reflect on the concepts of the practice in the construction of the concept maps, instead of creating 'the big picture' of behavioural biology.

Finally, it could be concluded that the domain-specific quality of the concept maps is sufficient to evaluate the students' understanding of the behavioural biology concepts. The analysis shows that most students are able to relate behavioural biology concepts adequately. In addition, it could be expected that students' conceptualisation increases further when the construction process of concept maps is improved.

9.5 Knowledge transition by recontextualisation

Transition is the capability of a student to adapt his or her understanding to another practice; this process requires recontextualisation. A design criterion of the LT-strategy is that recontextualising of earlier acquired concepts should be incorporated and that subsequently, the LT-strategy for behavioural biology education should consist of more than one practice. As we mentioned before, recontextualisation is a requirement for conceptual development, and stimulated through an adequate reflection. In the former section, we particularly analysed the interaction and reflection in the LT-strategy, and we concluded first that students' conceptual development was stimulated by reflection through the construction of concept maps, and second that the reflection phases provide for a possibility to change to another practice by evoking a new motive or steering question.

To investigate the knowledge transition, we consider two parts of the LT-strategy, namely the use of embedded practices in learning and teaching the stress mechanism in the first and second practice, and furthermore, the knowledge construction in the third practice.

First, to create a non-interrupted storyline, we used embedded practices to evoke motives for teaching and learning the stress mechanism. In our LT-strategy, embedded practices are used to relate scientific knowledge to the knowledge of the practice, and we claimed that recontextualising is not necessary when using embedded practices (section 6.3.3). In section 9.5.1 we answer the question whether embedded practices provide for conceptualization of the stress mechanism.

Second, we answer the question whether students are able to recontextualise, in particular when construction of knowledge is necessary to write an essay. Considering the use of concept maps as a tool for construction, we investigate if there is a relation between the quality of the concept map and the written essay (section 9.5.2). Thereafter, we analyse the students' understanding of behavioural biology concepts in their essays, because writing about an unfamiliar practice requires recontextualising. The third practice is unfamiliar for students, so they have to explore this practice with the knowledge acquired in the former practices. By writing an essay as an advice to the police about how to prevent riots and aggressive behaviour of hooligans, students have to use behavioural biology concepts in an unknown practice. Therefore, in particular in the third practice the result of recontextualising should be visible in the students' essays (section 9.5.3).

9.5.1 Knowledge transition with the use of embedded practices

Every change of practice should lead to recontextualising by students, because of the presumption that the meaning of a concept depends to some extend on the context in which the concept is used. In our LT-strategy for behavioural biology, we have used embedded practices in every practice. Therefore, as we have concluded earlier, we must pay attention to the use of embedded practices in an LT-strategy. Nevertheless, although we argued that recontextualising is probably not necessary for embedded practices (section 6.3.3) in this subsection we have to focus on how embedded practices are used in the LT-strategy and how students recontextualised the stress mechanism from the first to the second practice. Figure 20 shows where embedded practices are placed in the LT-strategy.

Stress mechanism in the first practice

In the scenario causation of behaviour is introduced by an article about dog stress (LTA[3.1]), and the students' motive is evoked from the (functional) question how a dog could defend itself. To understand the mechanism of stress, a practice is embedded (embedded practice 2, figure 20) about the General Adaptation Syndrome. In this embedded practice, another level of biological organisation is introduced: the molecular level. How are changes to and from embedded practices made in the executed scenario? Moreover, how are the concepts included in an embedded practice acquired?

In the executed scenario it appears that teachers and students make the change from the stress of a dog to the stress mechanism fluently. All teachers explain the stress mechanism by means of the graph (see figure 16). Teacher [2a_v] clarifies rising and fall of the line and introduces the role of the hormones adrenaline and cortisol. However, the clarification of the relation between hormones and stress is partly incorrect, as the following part of the class discussion illustrates:

T: "Adrenaline, nor-adrenaline and cortisol are hormones which are related to controlling stress. (…) these hormones provide for certain levels of stress. (…) Who is capturing hormones? On the inside of your body: how is the hormone concentration measured?"

S: "In the saliva, yes?"

T: "Yes, but how do your brains determine if there would be more or less hormone?"

S: "Levels!"

T: "How do you measure levels?"

S: "Sensor."

T: "What is this called in humans?"

S: "Sense."

T: "How do you call a stimulus?"

S: "Internal and external stimuli!"

T: "What is the external stimulus for a dog leading to stress behaviour?"

S: "Strange environment."

[2a_v, audio, lesson 3]

Hormones regulate the reaction to stress, not the level of stress. The level of stress is caused by a combination of stressors and coping. Hormones provide for the necessary energy for dealing with stressors, acute or chronic. Therefore, the teacher introduces a misunderstanding about the relation between STRESS, STRESSORS, and HORMONES.

Teacher [2c_v] also leads a discussion with his students based on the explanation of the stress mechanism, and after the reflection with his students about the perspectives function and causation, he changes to the development of behaviour:

T: "Time to change to the next perspective."

This is not the prescribed question in the teachers' manual, but he continues:

T: "We have noticed: experiences, education. Let's look at these. How can behaviour change?"

[2c_v, audio, lesson 3]

Students [2c_v] explored the stress mechanism as homework, and the class discusses the stress mechanism in lesson time. Students are able to explain the mechanism very well. After that, the teacher changes from the scientific practice to the life-world practice, from the causation to the development of behaviour. Students are able to name influences on habituation, such as education, environment, character of an organism, and experiences, so it appears to be an adequate change of practice.

Teachers [2a_h] and [2b_h] change to the stress mechanism abruptly. However, because of the storyline, the topic of stress is not a strange topic for students. Moreover, observations during the lessons [2a_h] show a great interest with the topic STRESS, providing their own examples, while the teacher [2b_h] asks a student to explain the graph of the stress mechanism. Teacher [2b_h] explains the stress mechanism, but both teacher and students link the three forms of defence (FIGHT, FLIGHT, FREEZE) to the differentiated parts of the graph instead of explaining it from the first phase of the STRESS

MECHANISM. Students think that an organism goes through all three stages of DEFENCE. Furthermore, these students are interested and contribute their own examples of (human) stress.

The stress mechanism in the second havo practice

At havo level research on weaning stress in young pigs is introduced after the introduction of the second practice (embedded practice 3, figure 20). The LTA[6.2] contains videos, and short articles about stress of pigs, while students have to answer questions that guide their thoughts from stressors to the physiological processes. Providing for an environment where an animal may exhibit natural behaviour is a way to reduce stress and increase welfare. The body requires energy to be able to respond to stressors and that energy is made available thanks to hormones such as adrenaline. The stress hormone cortisol is required for bringing the body in homeostasis again. If the stress mechanism is activated and cannot be discharged, chronic stress arises. Stress can be determined, *inter alia* by measuring the stress hormone cortisol in relation to animal behaviour. So, stress of pigs is introduced to students via studies on weaning stress and stress during pregnancy of pigs. These studies are introduced by watching a video wherein the researchers explain their investigations. Finally, the workbook states:

> "Hormones bring a message. Hormones act at the level of molecules. They are internal stimuli. They can indirectly affect the behaviour of an organism. In the video the researcher speaks about the stress hormone cortisol. How does this hormone work?" [havo, workbook, practice 2]

The above-mentioned description of the ‘storyline’ is elaborated in LTA[6.2] in the following way.

Following the teachers' manual, the steering questions should lead to an adequate understanding of the physiology of the stress mechanism. However, it appears that the change to the embedded practice is not easy to make, both by teachers and by students.

Students [2a_h] did not do their homework, so the teacher could not connect with the outcomes of the homework with the former lessons and decided:

> "Today we talk about the effect of cortisol. You can still read that…" [2a_h, audio, lesson 7].

A motive to learn about the stress mechanism did not evoke. Thereafter, the teacher [2a_h] summarizes the videos for the introduction of the welfare of farm animals (LTA[6.1]). Students have to view the videos outside the lesson time. The teacher resumes by viewing the videos about the research to weaning stress of young pigs. After that, the teacher is explaining the effect of cortisol. The following fragment shows a part of that explanation.

T: "Why should we look at that? That shows that cortisol is a hormone released during stress. What does that have to do with keeping farm animals?"

S: "If they have stress, there is less meat."

T: "Yes, less stress, better meat, and better welfare. How can you measure it? Researchers have done that. Then, you measure cortisol. (...). Cortisol is a hormone that goes through a particular system in your blood."

(...)

T: "What happens is that you observe something: change in your environment creates stress. How do you perceive that?"

S: "With your senses."

(...)

T: "Cortisol is in your blood. What does it provide for?"

S: "Stress."

T: "No, that is caused by a stressor. Then the cortisol is operating. What function does it have?"

S: ?

T: "Stress takes a lot of energy and cortisol makes sure everything runs smoothly. (…) What does this have to do with farm animals? You understand that welfare deals with how animals live in their environment, in this case, their production environment. (…) Where the animal lives affects its welfare. Two interests sometimes conflict with each other. Well, we are going to do an assignment about that."

[2a_h, audio, lesson 7]

The above-mentioned fragment illustrates that a motive is developed by the teacher to investigate physiology in relation to the environment, welfare and stress. Although the explanation of this part of the stress mechanism is quite deficient, it is observed that students are interested and begin to understand. In contrast, in class [2a_h] a change to the assignment about designing a welfare friendly pig stable seems to be effective, because it is observed that students understand what they have to do and where the assignment is aimed for.

The lessons [2a_h] were executed quite differently from the scenario, in particular because students did not do their homework very well. Therefore, the teachers had to spend more lesson time on LTA[6.2]. In addition, it appears that the physiology of the stress mechanism required more explanation than was expected.

Teacher [2b_h] also changes to the embedded practice, by saying: "stressors, again" [2b_h, audio, lesson 7]. His students have difficulty to link stress to the growth of the pigs. The next lesson the teacher [2b_h] concludes that students did not make their homework very well, so he summarizes the former LTA:

"We are always talking about stress. (…). And now it's about exploring stress. The question: can you measure stress? That is the central question of this lesson."

[2b_h, audio, lesson 8]

Students [2b_h] are motivated to know about the physiology of the stress mechanism. However, to save time for the test practice, the teacher and researcher decide to skip the assignment of designing a welfare friendly pig stable, which could reduce the value of the motive to know about the physiology of the stress mechanism.

Teacher and students [2b_h] also discuss the questions from the workbook to get a motive for understanding the stress mechanism. After viewing the videos about the welfare of farm animals, students are able to connect STRESS(ORS) with the living environment of animals. Thereafter, the relationship between stress and the growth of an animal (pig) must be elaborate, and LTA[6.2] about the weaning stress of pigs is discussed, as illustrated with the following transcription fragment:

T: "Question 58. Why does less blood go to the gut of piglets? (...) There is a disturbance. Less to the gut, but then it goes…?"

S: "Brains, muscles."

T: "What happens to a pig with stress? What does his body do? Actually, this is already revealed in the previous context. It wants to adapt, to deal with it. And then you can imagine that its muscles have to work. You can imagine that ... it is doing something. The blood is then extracted from the intestines."

[2b_h, audio, lesson 7]

It is clear that the teacher connects behaviour to the amount of blood in the pigs. Actually, the teacher had to take a step between the adaptation and the lesser stream of blood to the intestine, because before coping with a stressor, the alarm phase of the stress mechanism requires the use of muscles in the fight or flight of an organism. That is the reason why the blood goes to the muscles instead of the intestines. The teacher continues:

T: "What does the blood transport?"

S: "Oxygen and nutrients."

T: "Thus, that is less for the intestines."

(…)

T: "And: the fewer nutrients absorbed, the less growth. And here is the link between stress and growth, quality of meat. The better the animal feels, the better its growth and development, because its physiology -including the inside- with its cells, nutrients, and metabolism, is running better."

[2b_h, audio, lesson 7]

Although the students understand the link between WELFARE, ENVIRONMENT, STRESS, and GROWTH, a high amount of guidance from the teacher explaining the relationship between the concepts is required. In addition, the teacher indicates the link between metabolism and behaviour, which should help students to view the systems. The teacher explains:

T: "Here, moreover, that is aside, but here you also have a link to a completely different subject in biology. When talking about cell construction, etc., then you talk about nutrients that enter and exit the cell; you talk about breathing; you're talking about metabolism, but you never think of behaviour. Well, here you have a nice link between very different subjects: behaviour, and metabolism."

[2b_h, audio, lesson 7]

However, it is the only explicit moment in the execution of the scenario where the relation with another biological discipline is elaborated.

Then, the change to the research of stress is made to understand the physiological mechanism of stress. The teacher starts the lesson by referring to the last lesson, where the class looked at the concept STRESS. The students watch the video about weaning stress, and the teacher explains:

T: "And now, we look at the research of stress. (…) The pigs are happier, and thus the investigator said that they felt good. And the question for us now: is that really so? Can you measure it? Can you measure stress? That is the central question of this lesson. (…) Laurens, can we measure stress?"

S: "No, I don't think so."

T: "Can we research stress?"

S: "Apparently"

[2b_h, audio, lesson 8]

This fragment shows that the teacher relates stress to the growth of the pigs. If there is more stress, than there is more cortisol. In the research practice pigs received a piece of candy with a cortisol pill. Then, a student asks:

S: "But, if you have cortisol, then you have more stress?" [2b_h, audio, lesson 8]

It is clear that this student interchanges cause and effect, because when the mother pig got a pill with cortisol, the piglets were stressed and fearful. The following fragment shows that students are able to answer the questions of the teacher, but it is questionable if they are able to switch between levels of biological organization by themselves:

T: "Cortisol was dispensed to the mother, thus more stress for the mother. What kind of piglets did they get?"

S: "More stressed, with a light weight."

T: "How could you measure stress?"

S: "You can see that in their behaviour."

T: "Then, that needs to be interpreted. Now, we are going to measure. How?"

S: "It would be in the blood."

T: "Yes, we measure cortisol. We are going take a closer look at cortisol."

[2b_h, audio, lesson 8]

Then, the teacher gives examples of scarcity situations, and it is clear to the students that muscles have more priority than intestines in stress situations. Students understand that the working of the stress mechanism influences the growth of the pigs:

T: "Less to the intestines. Thus, fewer intakes of nutrients. What is the effect?"

S: "Less energy; you are thinner."

[2b_h, audio, lesson 8]

Thereafter, the teacher explains the HPA-axes, and refers to the menstrual cycle. The lesson is difficult, perhaps because the teacher is not following the instructions of the manual. On the other hand, for a better understanding of this embedded practice it would probably be better to explain the cycle systematically, without a class discussion. Now, students are guessing the answers to the teachers' questions.

In the workbook a question is asked why the investigated solution works against weaning stress. The correct answer is that when piglets adjust to a new situation, they have less stress. It appears that the answers of the students are diverse. Many students have the correct answer, as illustrated with the following quotes:

> "Less stress. So they are without their mother." [2b_h, workbook, Christel]

> "The piglets are progressively used to something." [2b_h, workbook, Marleen]

However, there are students who only wrote 'more play, more growth'. On the other hand, students empathize, using anthropomorphic language:

> "They feel happier and can play. Therefore they grow faster. They also live with the feeling that they are outside the loft. They get used to other things."
>
> [2b_h, workbook, Josien]

It could be concluded that no adequate motive was evoked to learn about the physiology of the stress mechanism, and it is necessary to look for fundamental improvements to the order of the LTAs of the second practice at havo level. Because of the question why students should have a motive for investigating the physiology of the stress mechanism, the practice could start with the activity of designing a stable instead of ending with it. In addition, the question how stress could be measured would be evoked from the conclusion that a stable, the environment of pigs, influences the welfare of the animals, and that it is necessary to know how the influence of the environment on behaviour of animals could be measured.
Therefore, summarizing, it appears in the LT-strategy that learning and teaching of the physiology of the stress mechanism in the havo classes is not easy, although the scenario mainly is executed as intended. Links with other biological disciplines are scarce, while cause-effect relationships are difficultly understood by students. Nevertheless, there seems to be an understanding of the physiology of the stress mechanism and its relation with behaviour.

Stress mechanism in the second vwo practice

The second practice at vwo level starts with a thought-experiment about students' own stress experiences, and the conclusion that stressors could be mental, emotional, and physical (embedded practice 4, figure 20). This LTA[5.2] links life-world practice experience to the embedded professional practice about sport training (embedded practice 5, figure 20). The steering question how to prevent overtraining evokes the need to know how to measure the stress level, which legitimizes the transition to the research of the overtraining syndrome. Another link is formed by the question regarding the similarities between the overtraining syndrome and burnout.

The executed scenario differs not remarkably from the intended scenario, and the embedded practices in the second vwo practice serve their purpose, namely providing motives for learning and teaching the physiology of the stress mechanism and the research of the overtraining syndrome. In addition, it is clear to students that from an ethical viewpoint the research on overtraining ought to be done with horses and not with humans, such as illustrated with the following quote:

T: "Why do we do research on horses and not on humans?"

S: "Horses are not aware what the research is."

T: "Why don't we take some athletes and overtrain them?"

S: "That's a bit silly."

[2c_v, audio, lesson 12]

The molecular level is introduced in the first article ‘Overtraining’, wherein is described how the hormonal system of overworked employees and overtrained athletes were exhausted. It appears that overtraining in humans is a serious problem, and that stress hormones play an important role. The first article in the workbook states that the sport is searching for a simple tool for trainers that quickly identifies whether their pupil is doing well, or tends to be overtrained. Furthermore, it appears that such an instrument is not easy to find. When using a questionnaire, you are probably already too late to recognize the problem of overtraining.

In the second practice, the emphasis on the stress mechanism is on chronic stress. The difference with the previous practice is that the second practice is not about the normal reaction to stress, but what happens in a different situation with prolonged stressors. Therefore, it is necessary that students understand what is happening in the body when stressors are involved. In chronic stress, the body does not recover enough (in time) and the organism has a risk of burnout or overtraining. When are you just in time? That question is examined in the study of overtraining in horses, since it is ethically not acceptable to do that with humans.

How is the above-mentioned storyline executed? Students [2a_v] studied the physiology of the stress mechanism by reading the article ‘stress mechanism’ in the workbook by themselves. Thereafter, at the end of the lesson time the teacher discussed the text. The students understand the stress mechanism, and are able to distinguish and explain the fast and the slow route of the stress mechanism. Nevertheless, the teacher answers most questions he asks his students. After the discussion students reflect online on the General Adaptation Syndrome with a programmed concept map as shown in figure 40. One student is able to do this exercise faultlessly. Because the lesson ends, students have to finish the exercise at home. During the next lesson the teacher fills the concept map in with help of the students in a logical manner, sometimes explaining, as is shown in the following part of the lesson:

T: "In the previous lessons you were engaged in behaviour and specifically with a particular component of behaviour; we looked at how the physiology, or how the body deals with stress. Your home assignment was a) to fill in this concept map {of the General Adaptation Syndrome, see figure 40} and b) to read the text about stress in horses. I want to immediately start with filling in this concept map. (...) What concept has to be there on top?"

S: "Hypothalamus."

(…)

T: You see a cascade of hormones. One after the other organs are stimulated to produce hormones.

(…)

T: "Then lipolysis. What is liposuction?"

S: "Fat removal"

T: "Good, fat removal. So, which cells do we have to write about here?"

S: "Fat cells."

T: "Which cells are left, then?"

S: "Liver cells."

T "Yes, liver cells. Liver cells are able to perform neoglucogenesis, remake glucose or release it."

(…)

T: "If we look here, we have a hint too, namely, of something that creates a higher oxygen concentration."

S: "Bronchioles."

T: "Very good. I wanted to hear that. We learned that last month from the story of cystic fibrosis. (...). Daphne, in your opinion, how would you change the flow of blood? What could you increase if you want more blood flowing through the body?"

S: "Through your heart.

T: "And what is your heart…?"

S: "Muscle."

T: "Yes, a big muscle, so, stimulate the cardiac muscle."

[2a_v, audio, lesson 9]

In the above-mentioned fragment two learning strategies are used by the teacher. First, he relates lypolysis to lyposuction. Second, he asks the right questions to stimulate students' thinking process, by relating to another topic students from another lessons about cystic fibrosis.

The concept map of the G.A.S. has a high degree of complexity for students, because it is written in the English language (and not Dutch), and probably unknown concepts are used, such as lipolysis. Nevertheless, we observed students who were able to complete the concept map for the first time flawlessly.

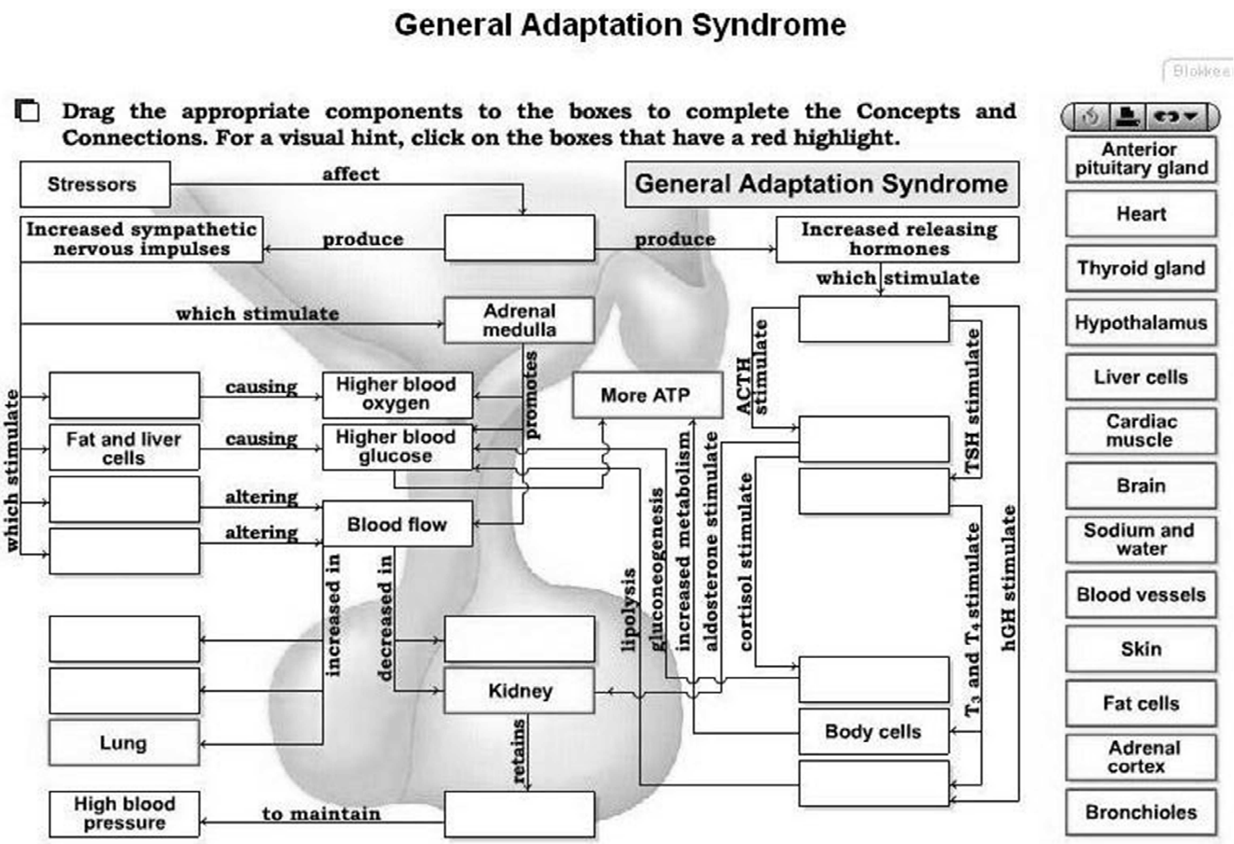

Figure 40. Concept map of the General Adaptation Syndrome as an assignment in the workbook at vwo level. Students have to move the concepts at the left side to the correct place in the concept map. The assignment can be retrieved from http://classes.midlandstech.edu/carterp/Courses/bio211/body1c.htm. (Retrieved December 2010)

Most students [2c_v] do not make the concept map of the G.A.S. at home, and the teacher changes to the discussion of the stress mechanism. Students are able to name the two routes of the mechanism (fast and slow) and Anne tells how the slow route works:

T: "In addition, we have seen the much slower mechanism and I will explore that slow mechanism with you. Anne, it was you who raised the questions? Can you briefly explain to me how the slow mechanism works?"

S: "So, you have the stress reaction, and then there comes the CRH hormone which in turn creates a release of ACTH hormone, which results in the stress hormone cortisol and that keeps adrenaline in control, so to speak, so that not all reserves are exhausted."

(...)

T: "Does cortisol also influence the previous steps of the stress mechanism?"

S: "That would be true."

[2c_v, audio, lesson 9]

Then, the teacher explains the feedback loop and he summarizes at the end of the class discussion:

T: "I return to the General Adaptation Syndrome. (…) Which is the first phase?"

S: "Alarm phase."

T: "The alarm phase: that is the route with the fast reaction. What phase do we find after the alarm phase?"

S: "Coping."

T: "Yes, the coping or recovery phase. The adaptation phase. The phase wherein you adapt to your environment, so you are able to cope with that environment, and hopefully you have not to reach the last phase. What was the last phase?"

S: "Exhaustion phase."

T: "Exactly! The exhaustion phase. You reach that when you have too much cortisol in your blood for too long." [2c_v, lesson 9, audio transcription]

The fragment shows that the teacher likes to explain the difficult physiology, and it is clear that students need this explanation.

In addition, although the relation between the concepts STRESS and STRESSORS (stimuli) seems to be clear for students, at vwo level three questions in the *workbook* make clear how students' conceptualization depends on the context.

Before the introduction of the physiology of the stress mechanism, an article about the role of a deregulated stress hormone system is placed in the workbook. Deregulated stress hormones lead to depletion, and the conclusion of the article is: "It is about recovery". In the article, a brief introduction to the physiology of the stress mechanism is given. The aim of the questions asked in the workbook is that students understand the relation between the stress mechanism, overtraining and physical stress. In particular, three questions give us more insight into students' reasoning.

Question 57 ("When does stress occur?") asks about the causes or circumstances of stress. The students' answers show that they are able to perceive the relationship between the environment and organisms. For example, students name stressors, an unfamiliar environment, pressure to perform, and explanations such as the amount of cortisol, such as illustrated with the following answers to question 57:

"By stressors. When people are uncertain because they come into a new situation, or if they are in a situation in which they experience negativity, (…)" [2a_v, workbook, Stephanie]

"New, unfamiliar environment, pressure to perform." [2a_v, workbook, Annelot]

"Overload, stressors, external stimuli." [2c_v, workbook, Joeri]

"Stress occurs when the amount of cortisol increases." [2c_v, workbook, Ilse]

It is notable that the ‘pressure to perform’ is noted. It shows students' contextual perception, because stress is related to achievement in the article.

The next question (q59) handles the relation between (physical) training and stress. Why is training a form of stress? Students answer on two perspectives: the physical and the psychological level, although there are students who see the ‘big picture’, as illustrated with the quote from Armelle:

"When you are learning stress always occurs. You learn something new." [2a_v, workbook, Armelle]

Rianne emphasises the physical side of training:

"Your body produces cortisol to be able to cope with the rigors of training." [2a_v, workbook, Rianne]

The physiological level is mentioned when students refer to the pressure that is accompanies training and performance, such as the following quotes illustrate:

"You must perform and always give 100%" [2a_v, workbook, Tom]

"You wish to train in order to perform well. That provides a mental pressure." [2a_v, workbook, Paul]

"You feel that you should perform. That gives time pressure, therefore stress." [2c_v, workbook, Joeri]

Some students relate the requested performance with the production of stress hormones:

"Because you have to perform, you can become insecure, because you're afraid you cannot meet the requirements and then stress hormones are made." [2a_v, workbook, Stephanie]

"The daily efforts cost much energy and then stress hormones are made." [2c_v, workbook, Ilse]

It appears that students are able to reason about the stress model, although some students relate stress to the pressure to perform. In that case, they probably associate the question with their own experiences. Nevertheless, those students understand that in case of stress, stress hormones are released.

So, in the model of the stress mechanism a time of recovery is necessary to decrease the levels of the stress hormones. At this point, students are confronted with question 62, where they have to explain why a runners' schedule includes an alternation of running and walking. Do students understand that it is about recovery? It appears that most of the students understand that principle, as is shown in the following quotes:

"To promote recovery." [2a_v, workbook, Jan]

"That is good for your muscles. Your body can restore." [2a_v, workbook, Tom]

"Then fall the corticol/adrenaline levels, so you are not stressed during a long period." [2a_v, workbook, Rianne]

From the above-mentioned quotes it appears that students understand the model of the stress mechanism. Furthermore, they are able to switch from the molecular level to the level of the organism. It is not observed that students relate a single cause such as a hormone to specific behaviour of the organism.

Summarizing, the lessons were executed quite differently from the scenario, in particular because the students did not do their homework very well. Therefore, the teachers had to spend more lesson time to the LTAs. In addition, it appears that the physiology of the stress mechanism requires more explanation than was expected. Nevertheless, it seems that students understand the model of the stress mechanism.

It could be concluded that students recontextualised the concepts of the stress mechanism between the first and the second practice. It is not indicated that the use of embedded practices in the storyline disturbed the recontextualisation process. With the exception of the embedded practice in the second havo practice, embedded practices are placed logically in the scenario, providing the possibility of learning and teaching about the stress mechanism. Two problems are noted. First, the change of the level of organisation deserves more attention in order to develop students' understanding of the connection between behaviour (stress) and hormones. Second, the scenario should provide for an LTA wherein the stress mechanism is explained or explored. Despite these notions, the use of embedded practices is a valuable addition to the use of authentic practices in biology education when they have a logical place in the storyline, eliciting motives for students to know more.

9.5.2 Concept maps as a tool for construction of knowledge

In the subsection 9.4.3 we reconstructed the course of the reflection activities in the reflection lessons, including the use of concept maps as a reflection tool. In the third practice, concept mapping is also be used as a tool for construction of knowledge. An important point of attention is the degree wherein students are able to create a coherent concept map, which indicates for understanding the meaning of concepts in relation to each other. We consider, finally the constructed concepts maps of the third practice of the LT-strategy, because these concept maps were constructed without the help of the teacher, and should indicate for students' conceptual development.

Short overview of intended third practice

Students have a motive to change from the practice of farm animals or overtraining, and the video of the unexpected aggressive behaviour of a child focuses their attention on human aggression. The teacher introduces the topic of aggression, letting students read an article "Aggression belongs to life" (in Dutch) (Dagbladen, 1999).

After the introduction, students have to construct a concept map of aggressive behaviour. After two concept mapping assignments, concept mapping saturation was noticed, and some students reacted: ‘No, not again’. However, although even after a holiday students [2a_v] remember many concepts, students [2c_v] ask the teacher after the second practice what they have to learn for the test. Do they understand the aim of reflection through concept mapping? In the class discussion, they are able to mention the concepts and their meaning, so the teacher concludes at the end of the dialogue that he believes that his students have learned something. However, another student, Stijn, has a different experience. He says:

> "You can go through this for a very long time. Every time I discover new links" [2c_v, observation P3, Stijn]

Finally, they have to write the essay (in groups of two). The assignment is introduced by an observation report of a behavioural biologist about a riot. An essay should start with posing a problem, then arguing from the three perspectives for a solution, and ending with a conclusion about possible solutions.

Do students write essays according to the assignment when they construct a concept map from a behavioural biology view? Because in this assignment the use of the three perspectives is prescribed, we want to investigate how the perspectives are used in both concept maps and essays.

The 47 submitted concepts maps show a large diversity, as could be expected after what we have concluded in the former subsection about the technical quality of the constructed concept maps. In the third practice, students constructed concept maps with an average of 13 concepts (stdev = 5). In 80% of the concept maps the necessary linking phrases between concepts are not indicated, and furthermore, only a few behavioural biology concepts are reported: 25% of all concepts are behavioural biology concepts (average of 3 behavioural biology concepts per concept map); the other concepts are related to the practice. These findings about the technical quality of the concept maps are similar to the findings in the former subsection.
Furthermore, it appears that students who construct an extensive concept map also used relatively more behavioural biology concepts, as shown in figure 41.

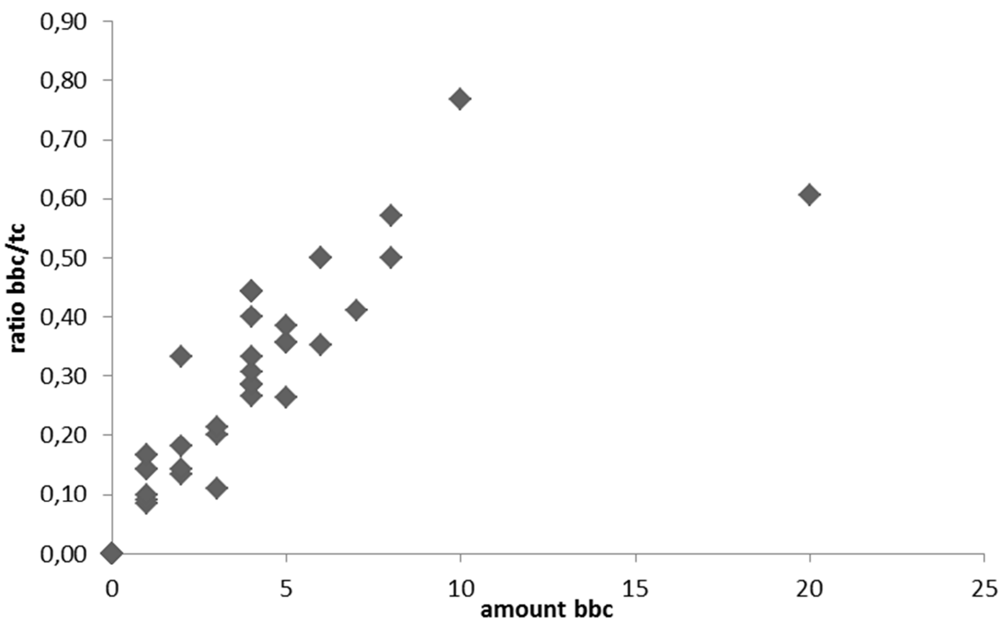

Figure 41. Relation between the number of behavioural biology concepts (bbc) in a concept map and the ratio (tc=total number of concepts) from students' concept maps constructed in the third practice.

Students noticed the perspectives differently. 55% of the concept maps did not contain any perspective. 17% of the concept maps contain one perspective (mostly ‘causation'), while two perspectives are not found. 28% of the concept maps contain the three perspectives.

To compare the concept maps with the essays, we selected concept maps with different ratios of bbc/tc. The selection of concept maps and essays is presented in the figures 42-46.

The concept map shown in figure 42 is without linking phrases and behavioural biology concepts (ratio bbc/tc = 0.00). Nevertheless, Shinook & Geeske have tried to use the concepts, noted in their concept map, in their essay. For example, they use the concept DOMINANT BEHAVIOUR speaking about the attitude of police officers:

> "The last tip is that a police officer should be showed dominantly, because you show that you are the boss and the fans have to listen to you." [2a_h, essay, Shinook & Geeske]

The concept DOMINANCE is introduced in the first practice about caring for your dog, as a kind of dog behaviour. Shinook & Geeske are able to use the concept behaviour in a flexible manner, although it is debatable whether it is the correct use of the behavioural biology concept of dominancy.

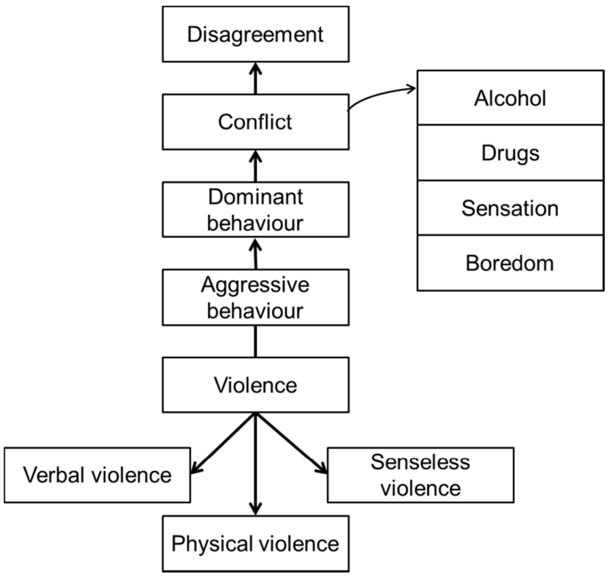

Figure 42. Concept map [2a_h, cmap P3, Shinook & Geeske]. Ratio bbc/tc 0.00.

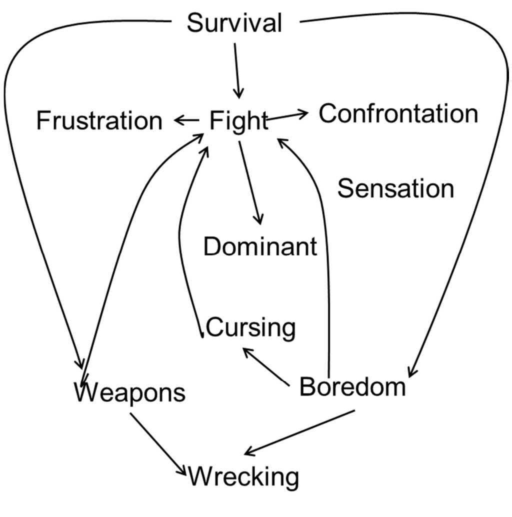

Figure 43. Concept map [2a_h, cmap P3, Nick]. Ratio bbc/tc 0.10

Nick's concept map (figure 43) has a ratio bbc/tc of 0.10. The concept map is without linking phrases, behavioural biology concepts (except survival), and hierarchy in concepts. Nick's essay is not including any behavioural biology concept and did not answer to the demands of the assignment.

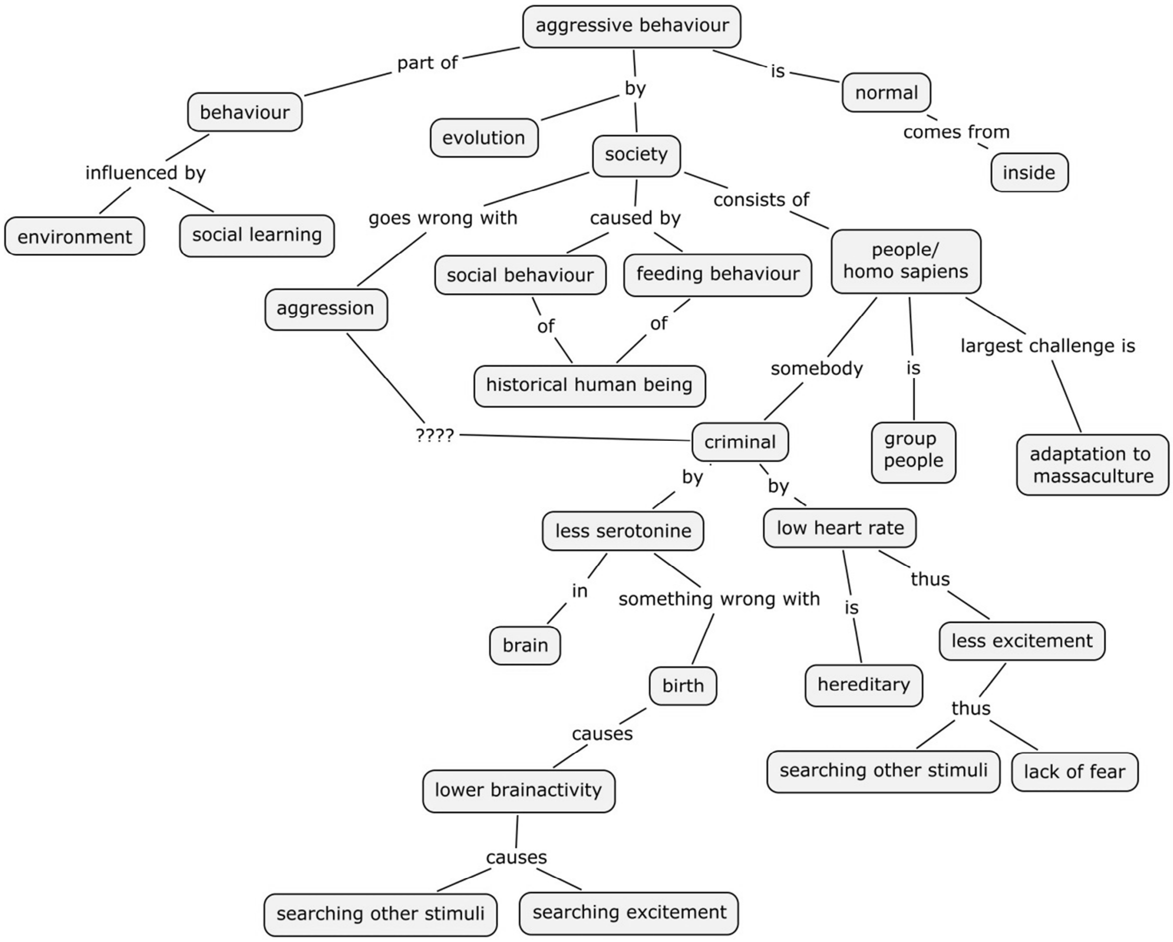

Figure 44. Concept map [2c_v, cmap P3, Michelle]. Ratio bbc/tc = 0.11.

Michelle did use the computer program CmapTools[28] for designing a concept map, and so she used linking phrases in a very large concept map (figure 44). However, it is a concept map with a ratio bbc/tc of 0.11. In addition, Michelle does not use this map in the construction of her essay. In the essay, we searched for the 15 concepts of the concept map and found only 4 occurrences (AGGRESSION, BEHAVIOUR, AGGRESSIVE BEHAVIOUR, and STIMULUS).

[28] http://cmap.ihmc.us/ (Retrieved February 2012)

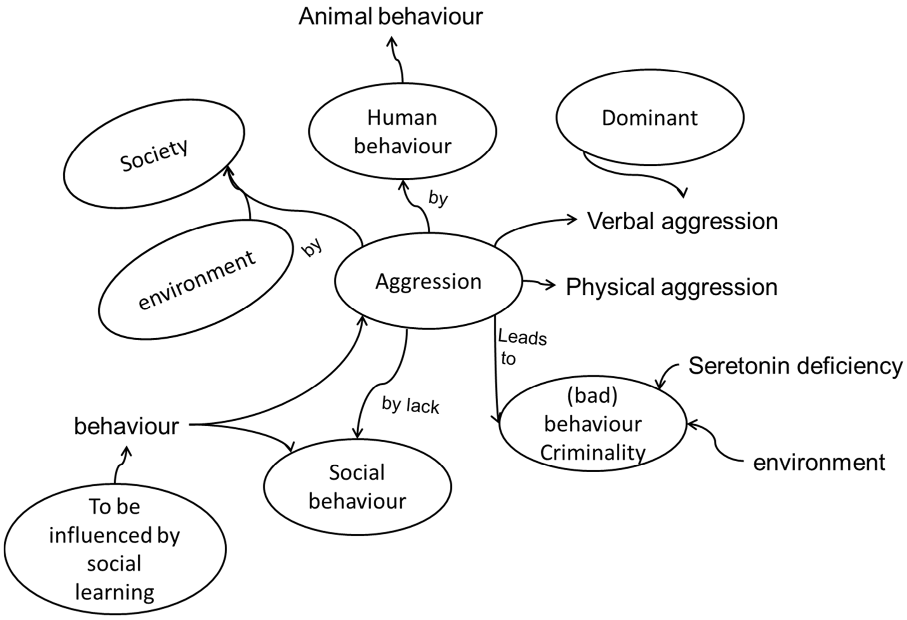

Figure 45. Concept map [2c_v, cmap P3, Thomas & Joeri]. Ratio bbc/tc = 0.20.

In their essay, Thomas & Joeri show understanding of concepts as DEFENCE (and FIGHT-FLIGHT-FREEZE), and INTERNAL and EXTERNAL STIMULI and STRESSORS, although their concept map shows only occasionally linking phrases, and is not including many behavioural biology concepts (ratio bbc/tc = 0.20; figure 45). In addition, Thomas & Joeri used images of the brain in their essay to explain the pathway of serotonin.

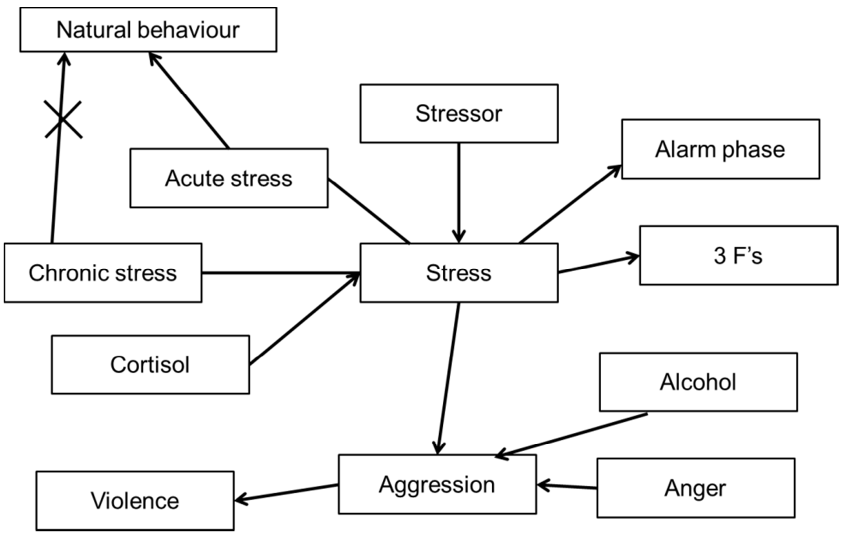

Figure 46. Concept map [2a_h, cmap P3, Tim]. Ratio bbc/tc = 0.50.

The concept map of Tim (figure 46) includes no linking phrases, but has a ratio bbc/tc of 0.50. Although he uses behavioural biology concepts, no perspectives are noted. Despite of the lack of linking phrases and perspectives, Tim uses behavioural biology concepts in his essay (such as fight-flight-freeze) from two perspectives.

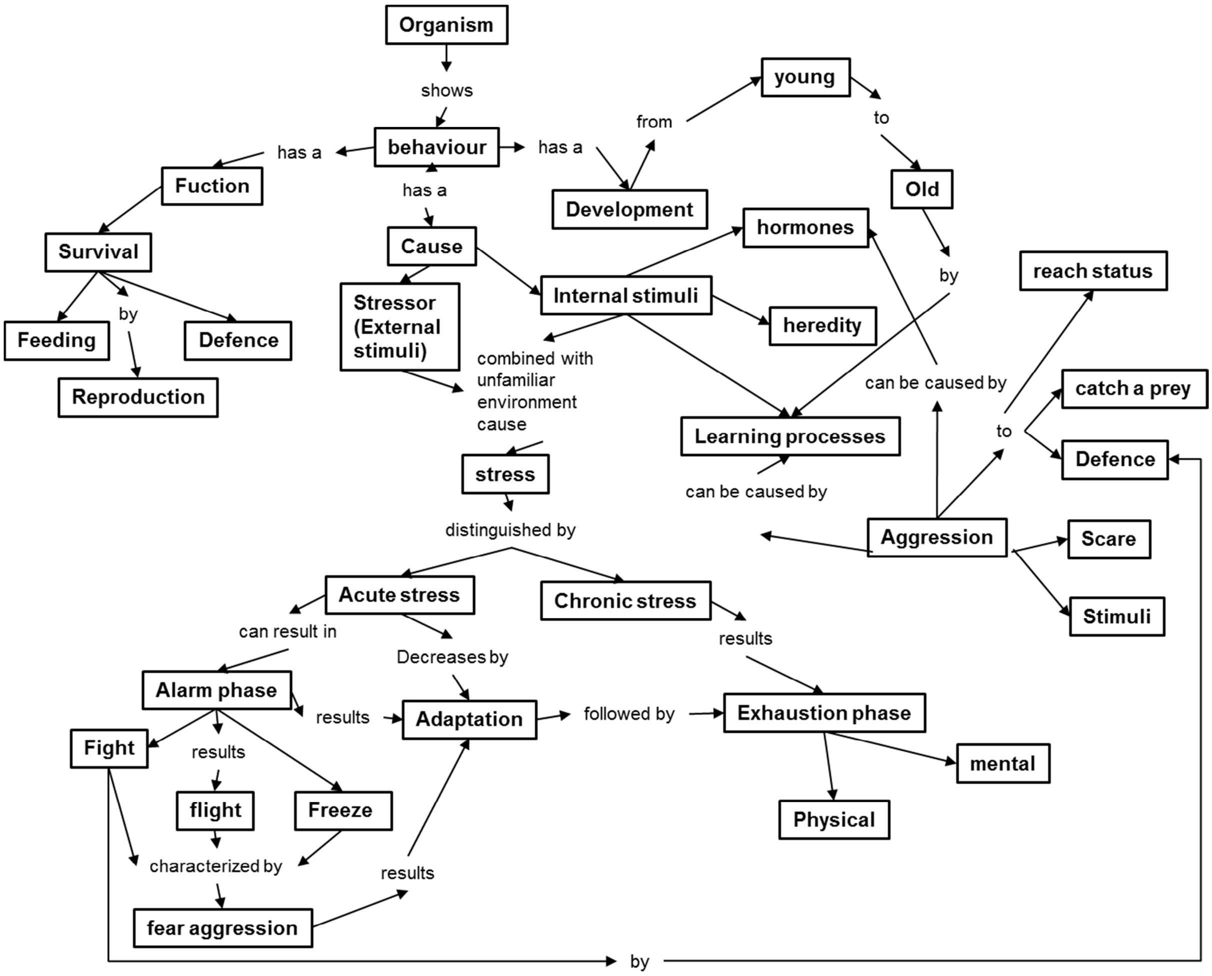

Figure 47. Concept map [2c_v, cmap P3, Lise-Milou]. Ratio bbc/tc = 0.61.

The closest correspondence between an essay and a concept map is found in the work of Lise-Milou. She writes in her essay as an introduction:

> "For many football matches riots occur between supporters of the guest team and the home team. In these matches riots are so bad that many police officers should be involved. The examples are regularly on TV. You will wonder, do these people even care about the sport or are they just hooligans out to an afternoon fight? Why do they do this? And how can this behaviour be prevented? Riots have everything to do with human behaviour, the impact on each other, and behaviour in a group. When people are in a group, they quickly have a big mouth and dare to do more. Behaviour has a function, a cause and development. All these things I put in a chart with all their consequences." [2c_v, essay, Lise-Milou]

Lise-Milou uses linking phrases and all three perspectives with behavioural biology concepts (figure 47). Lise-Milou gives a perfect description of behavioural biology in her essay, although a well-structured transition to the topic ‘preventing football riots’ is lacking. However, she concludes that

> "In the stadium flight routes must be available for people who are concerned and want to flee away." [2c_v, essay, Lise-Milou].

Again, as we noticed in the concept map and essay of Shinook & Geeske (figure 42), Lise-Milou also uses the behavioural biology concept FLIGHT in a flexible manner. In other words, students demonstrated in their essays that they are able to use concepts, either from behavioural biology or not, flexibly in another practice.

The domain-specific quality of the constructed concept maps in the third practice is indicated by the degree of the use of behavioural biology concepts, perspectives, and the use of propositions (linking phrases). It appears that students, who constructed a concept map with a low ratio bbc/tc, also wrote an essay containing fewer behavioural biology concepts and perspectives. In contrast, students wrote a better essay, when they constructed a high ratio bbc/tc concept map.
Therefore, we conclude that when students can make a high quality concept map they understand the meaning of and the relationship between concepts. Additionally, in the process of construction of a concept map, their understanding of behavioural biology concepts increases, as shown in the following scheme:

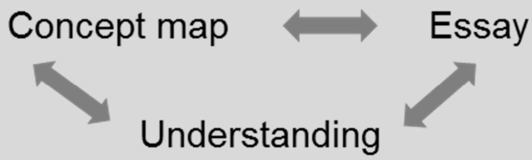

Figure 48. Scheme of the interaction between students' understanding, concept mapping and essay writing.

It appears to be important to pay attention to an adequate construction of concept maps.
We also can conclude that the LT-strategy for behavioural biology, containing several practices, invites students to recontextualise their knowledge, both with qualitatively inferior and superior concept maps.

9.5.3 *Students' knowledge of behavioural biology in their essays*

In the final assignment, students have to write an essay about how to prevent riots. They have to write this from the viewpoint of a behavioural biologist. In the essay, four sub questions had to be answered:

- What is the problem?
- What are causes of the behaviour of hooligans?
- Why do people become aggressive? (What is the function of behaviour?)
- Which solutions and recommendations could be presented? Which arguments do you have?

Students should use their concept map about aggressive behaviour and have to explicitly process the function, causes, and development of behaviour.

Table 23 shows the relative frequency of essays distinguished through the number of used perspectives. It appears that students pay more attention to causes than to the function and the development of behaviour. This is explainable, because the assignment prescribes to start with causes of aggressive behaviour. Another reason could be found in the former practices where little attention is paid to the perspective of development. A third explanation is that causal thinking is a common reasoning method. Students argue by causal reasoning that the problem of riots could be solved when the causes are taken away.

Table 23. Relative frequency (%) of students' essays considering the perspectives of Tinbergen at havo level (n=39) and vwo level (n=27).

	havo	vwo
no behavioural biology concepts used	20%	15%
Use of the perspective causation	44%	41%
Use of the perspectives causation, and function	31%	37%
Use of the perspectives causation, function, and development	5%	7%

From table 23 we conclude that more than 80% of the students use one or more perspectives of Tinbergen in arguing their statements about preventing aggressive behaviour. Nevertheless, 20 % of the havo students and 15% of the vwo students have written an essay that is no more than a nice form of creative writing without links to behavioural biology. Furthermore, considering the conclusion in section 9.4.1 that too little time could be spent in exploring the perspective of development, it appears that 36-44% of the students did use two or more perspectives, which we can consider as rather low. A few students wrote an essay that could be considered examples of ‘good practice', using different perspectives and showing a correct understanding of the behavioural biology concepts. The best-written essay is shown in Appendix B.

Problem description in the essays

Several students start the introduction of their essay by emphasizing their own experiences with football or in their role as a behavioural biology researcher, such as shown in the following quotes:

"I have been a supporter myself for two years, also at outdoor games as with Feijenoord[29] and if they then lost, they hit against the fences and curse at us when we ran to the buses. (...). Quite currently, and not pleasant to do if you see how the fence is almost gone and the police are in a powerless position."

[2a_h, essay, Joris & Rob]

"We are two behavioural biologists who want to prevent riots in future through reducing irritation."

[2a_h, essay, Jilles & Sebastiaan]

These fragments show that essay writing is a challenge that appeals to students' attention in a story and to creativity in using the acquired concepts, even in biology education. Joris and Rob spontaneously wrote:

"Joris and I thought it was fun and instructive to participate in a new method of biology teaching. We also believe that this is a challenging way and therefore perhaps better than books." [2a_h, essay, Joris & Rob]

The problem is clear for students: hooligans cause damage through riots, and aggressive behaviour should be reduced. Riots are a societal problem, and police officers deal in particular with aggressive people, such as football hooligans.

[29] Dutch soccer club

The perspective of function

From a behavioural biology viewpoint, SURVIVAL and NATURAL BEHAVIOUR are the main concepts of the function of behaviour. From the students who have written about the function of behaviour some of them have studied several sources about aggression. Joost & Tom wrote:

> "Every child needs a healthy dose of aggression and violence to explore its life world and to learn. (..) Biologically, aggression is a highly functional form of communication to survive as a species." [2a_v, essay, Joost & Tom]

This statement is composed from information from two websites about aggression[30] and Joost & Tom are able to combine this information into a relevant line of reasoning. However, not every student understood the concept FUNCTION very well, as is illustrated with the following quote:

> "The function of aggression in the case of football riots is: to abreact your frustration at the supporters of the other team." [2c_v, essay, Joeri & Thomas]

Here, in this fragment, function is understood as the function of the behaviour of a population, (function of riots), which has a societal meaning. It could be considered as an example of recontextualising. Furthermore, it shows that students are able to use behavioural biology concepts at the biological organization level of the population. However, this statement is an exception. Most students view aggression as a form of defence, needed to survive, which for example appears from the following quotes:

> "Aggression helps you in difficult situations. Alertness! Better defence." [2a_h, essay, Tim]

> "Man has been trying to survive since he was born in a world he does not know. This can be done by adjustment (adaptation) or by your own way and doing what you like. A form of defence is aggressive behaviour. [2c_v, essay, Chenna & Martine]

Note that the concept NATURAL BEHAVIOUR is used in the definition 'what normal is to do'. NATURAL BEHAVIOUR is mostly correctly understood by students, defined here by Roy as:

> (…) the behaviour that we might exhibit in former times in the wild (...) because in former times aggression was required to survive. Man is originally a 'group man'. (...) We live more and more individually and it is also unclear who is dominant and who is recessive." [2a_v, essay, Roy]

Roy is able to use behavioural biology concepts correctly, with the exception of the concept RECESSIVE, a concept from genetics. More students link aggression to the concept DOMINANCY, which they have acquired in the first practice. The following quote shows students' understanding of the concept of DOMINANCY in relation to aggression:

> "Hunting-instinct. Dominant behaviour helps people to be successful and get what they want. Aggression occurs when people are not successful or if others come close in the territory." [2b_h, essay, Carla, Femke & Josien]

[30] http://nl.wikipedia.org/wiki/Agressie and http://studium.hosting.rug.nl/2007_Activiteiten/agressie-koolhaas.htm (Retrieved April 2011)

However, the concept of NATURAL BEHAVIOUR evokes also different understandings by students in relation to riots. For example, Hanna wrote:

> "Normal behaviour is natural behaviour. The hooligans did not show natural behaviour." [2b_h, essay, Hanna]

In this fragment Hanna poses that the behaviour of hooligans is not normal, and is therefore not NATURAL BEHAVIOUR, while Romée argues the opposite:

> "When threatened people are going to defend themselves. This is natural behaviour." [2a_h, essay, Romée]

Perhaps the difficulty in explaining group behaviour is a possible explanation for this difference in argumentation, because group behaviour could be seen as a higher degree of complexity in behaviour. In addition to the behaviour of an individual organism, with group behaviour another biological level of organization is introduced, including other characteristics. One student quotes a definition of aggression and argues in his essay from this definition from the individual to the group:

> "Any man is aggressive. Aggression is the ability of people to defend them from attack, to launch attacks themselves and to be able to collect food. (…)" [2a_h, essay, Max]

So, according to Max the function of aggression is that:

> "Ensuring its position within the group contributes to riots." [2a_h, essay, Max]

and

> "Through aggression a group radiates power" [2a_h, essay, Max]

Max names stress hormones, frustration, and group pressure as causes, and his solutions are for example reducing group pressure through many travel options, and splitting up groups of supporters.

The perspective of causation

Students know that internal and external stimuli evoke (aggressive) behaviour, and they mention a diversity of stimuli:

- The influence of the group. Seeing other people, rivalry between groups and also seeing the police does evoke aggression.
- Stress, frustration.
- Boredom or for kicks.
- The use of drugs and alcohol.
- The environment: the organization of the football stadium.
- Genetic factors, such as a reduced serotonin production.

Furthermore, when students use behavioural biology concepts, they describe the relation between stimuli and stress (mechanism), as is illustrated with the following quotes:

> "That is because your opponent is seen as an enemy; in biology this is called a stressor. Through that stressor a substance is released in the supporters, called cortisol. Alcohol, which increased the progesterone effect, in particular the Fight mode." [2a_h, essay, Mark]

"Violence and aggression are evoked when the stress level is above a certain level. This level varies per person. In turn, stress arises through unexpected events, threats, an unfamiliar environment or certain behaviour from others (getting carried away). What are stressors in riots?" [2a_v, essay, Anna & Leon]

"That people can be so aggressive, often because people are not safe, familiar or at ease. Many people are stressed when, for example, it is not clear where the exit is. Many people stress out when a panic evokes. Unable to adapt to mass culture (scientists say)." [2a_v, essay, NN]

In the workbook article "Aggression belongs to life", the author writes that men show more aggressive in behaviour than women, because of the amount of testosterone, but also because of a developmental difference in the maturing of the brain. Students process this cause in their essays, but when they write about solutions, they refer more to EXTERNAL than INTERNAL STIMULI.

The perspective of development

Although not many students write explicitly about de development of behaviour as a separate topic, some of them pose statements about the development of aggressive behaviour. All of these statements have elements of education. The following quotes are illustrations of such statements.

"Most supporters who show aggressive behaviour grow up in disadvantaged neighbourhoods where criminality is high." [2b_h, essay, Floris & Francien]

"Parents have a great influence at their children. Sometimes through physical beating: no good example. (…) The biological side is difficult to tackle: medicine against aggression. (…) Searching for the solution at the cause: the development of the behaviour: the growing up of the hooligan." [2a_v, essay, Joost & Tom]

"1. You can define aggression as something that is genetically determined, what is passed from parents to child. 2. Aggression can result from accumulation of traumatic events in your life. 3. You also can define that aggressive behaviour is learned. This is mainly an imitation and contagion of the behaviour of others. 4. You also can define aggression as a response to circumstances in which a person is threatened or in response to the difficulty in accepting situations." [2c_v, essay, Stijn & Roos]

Solutions for the problem of riots

Students describe solutions that are linked to the causations they mentioned, as Michelle expresses:

"In order to remedy this problem, you first must know the cause. The cause of this problem is largely unknown. Is it because the fans have a difference of opinion and want to show their opinion by riots? And thus show that they think they are right? Or might the cause be a lot deeper? Aggression is a form of stress. Could this have something to do with it? Or the fans cannot stand for their football team to lose?" [2c_v, essay, Michelle]

Students have to reduce or avoid stimuli, and Roy concisely indicates:

"Reduce stress through limiting stressors." [2a_v, essay, Roy]

In addition, many students propose to solve the problem of riots by splitting up groups of supporters, reducing group size or avoiding that hooligans see much police (police officer in plain clothes). In addition, students assume that the deployment of stewards known by the people reduces feelings of being threatened and therefore reduces stress. Therefore, although not well outlined, the contours of the same solution as in the authentic work of Adang are visible in the answers of the students.

Furthermore, a general remark about the execution of the assignment of the essay could be made. Writing an essay was an unknown exercise for students. Therefore, the process of writing is guided in the workbook. It appears that many students take too much freedom in execution, because they did not read carefully the instructions, while other students follow the instructions to the letter without creating a storyline in their essay.

Summarising and conclusions

Nearly 80% of the students use 1 or 2 perspectives (causation, function). The perspective of development of behaviour is underexposed. The 20% of students, who did not use perspectives, did not follow the instruction of the assignment very well.

Students are able to argue from the view of a behavioural biologist, because they live in their role. The contours of the same solutions as in the authentic work of Adang are visible in the essays.

Students used most behavioural biology concepts correctly. Although scarce, an exception is the understanding of the concept function. In addition, NATURAL BEHAVIOUR is occasionally understood from the judgement that riots are not normal.

Furthermore, the change of level of biological organization, from the organism to the population, seems not to be problematic.

These results indicate that most students are able to use some of the acquired behavioural biology concepts in an unfamiliar practice. Considering the concept maps and the essays, it appears that the success in constructing a concept map and a final essay is determined by students' prior knowledge, context, and the understanding of the concepts. It seems that the more meaningful relationships a student can show in their concept map, the better s/he will execute the assignment of writing. Therefore, it should be discussed how the relation between the reflection by the construction of concept maps and knowledge transition in a new practice could be improved.

Recontextualisation is a necessary condition for a correct execution of the essay assignment, and it could be concluded that the LT-strategy provides opportunities for recontextualising, although not all students succeeded.

9.6 Summary and conclusions

The first research cycle is considered as a rapid prototype of the LT-strategy for behavioural biology education. From a quick scan of the test results in the first research cycle, we concluded that students express incorrect connections between the perspectives of Tinbergen, sometimes caused by handling different descriptions of the concepts. Students stay in concrete examples instead of understanding the abstract concepts. Therefore, four main improvements to the scenario were made in the second research cycle. First, a renewed focus lesson; second, an increased length of the lesson series; third, an applied profoundness for students on both educational levels (havo and vwo) and on content level by introducing the General Adaptation Syndrome; and fourth, the use of more reflection LTAs, including the use of concept maps as a reflection tool.

To evaluate whether the LT-strategy for behavioural biology is adequate, we investigated students' conceptual development by considering the **interaction**, **reflection**, and **construction** in the executed scenario. For that purpose, three educational themes were selected. First, we reviewed the development of a central steering question in the focus lesson. Second, we considered students' conceptual development in the evaluation of the interaction and reflection in the executed scenario. Third, we investigated the knowledge transition by recontextualising, evaluating the construction of knowledge. In this section, we review the conclusions of this chapter, in order to present an overview of students' conceptual development.

Development of a central steering question in the focus lesson

The focus lesson is intended to develop the central steering question, and the three perspectives of Tinbergen. Therefore, the didactical approach in the second version of the LT-strategy contained four elements. 1. Students watched unexpected behaviour of a well-known animal, a dog. 2. Students explored possible explanations for this unexpected behaviour, and categorized these explanations according to the perspectives of Tinbergen. 3. To create a non-interrupted storyline, the focus lesson is in line with the subject of the first practice (how to care your dog). 4. A well-prepared focus lesson is strictly prescribed in a teachers' manual. The teachers were asked to follow the instruction.

In the reconstruction of the executed focus lesson, we concluded that observation of the unexpected behaviour of a dog increases the students' awareness of behaviour as a biological subject, and they are stimulated to investigate why that dog behaviour did occur. However, the central steering question "Why do they do that?" is more implicitly posed by students, and explored by the development of the perspectives of Tinbergen. With this development, common language for exploring the perspectives in the next practices is presented. In addition, the restriction to the behaviour of one animal species (the dog) instead of several different species creates a non-interrupted storyline. Therefore, it appears that students elicit a motive for exploring the first practice. Furthermore, we concluded that the teachers' manual provides for adequate preparation of the teacher, which is shown by the different courses of the lesson when teachers either, improvised or followed the manual. Overall, we conclude that the focus lesson of the scenario conforms to its purpose, and that the adaption of the scenario was effective.

Students' conceptual development

In section 9.3 the following three questions were answered.

1. To what extent did students understand the three perspectives with their respective behavioural biology concepts?
2. To what extent do the reflection phases contribute to the students' conceptual development?
3. To what extent do the concept maps as a reflection tool contribute to the students' conceptual development?

Interaction in the LT-strategy is investigated by the analysis of the students' participation in an educational practice, which results from the interaction between teacher and students in the class discussions, and with the learning materials.
Studying a practice, students made a list of the concepts that they marked as important for that practice. All listed concepts are categorized in three categories: behavioural biology concepts, context related concepts, and concepts of the stress mechanism. The lists of the first and second practice contain merely concepts of behavioural biology and the stress mechanism, while students wrote the most context-related concepts in the third practice. These differences reflect the emphasis in the practices very well, underlining what we stated in our view on learning and teaching that knowledge is context-related. In addition, another difference between the first two practices and the third one is the degree of guidance in the construction of knowledge. In the first and second practice, the list of concepts was made to reflect on the practice, while in the third practice a list of concepts was meant to prepare for writing an essay. The categorization of the listed concepts according to the three perspectives shows that students often do not explicitly note them. However, from the self-evaluation and the class discussion, it appears that most students are able to recognize the perspectives on behaviour.

We can conclude that in general the scenario is executed as intended, although organizational difficulties evoked. Teacher behaviour and preparation could be more adequate, and some extensions were made in the LT-strategy, such as a class discussion about WELFARE, NATURAL BEHAVIOUR, and the STRESS MECHANISM. Teachers explained in their feedback that they felt uncertain, because they did not check the behavioural biology concepts very well. It could also be concluded that teachers (1) have some difficulties with the understanding of some of the concepts themselves, (2) take too much time for explanation, and (3) regularly forget to evoke motives for learning. Consequently, the teachers' guidance could be improved by focusing more on the behavioural biology concepts and their coherence.
The analysis of the interaction in the class discussions shows that the LT-strategy structures the students' conceptual development, distinguishing the three perspectives on behaviour with their accompanying concepts. Therefore, we conclude that students' awareness of behaviour is demonstrated.

Reflection activities in the LT-strategy are particularly elaborated at the end of the first and second educational practice. Students made a list of concepts, followed by the construction of a concept map. In addition, a class discussion about a concept map was executed, to create a ‘big picture’ of the behavioural biology concepts. We conclude that an adequate reflection time was programmed in the second research cycle, and it seemed that students' conceptual development was effectively stimulated by reflection through the construction of concept maps. The effective use of concept maps as a reflection tool can be improved when students (and teachers) further develop skills for concept mapping.
Teachers and students do not always understand the aim of concept mapping. In the havo classes, the concept mapping assignment was too open, and more guidance was needed. It was noticed that the havo students did have more difficulties with causal explanations than vwo students. Vwo students

also have difficulties in starting the design of the concept map and deciding which concepts should be included.

We investigated the quality of concept maps, both the technical quality and the domain-specific quality. Only approximately 27% of the students' concept maps meet the condition of having linking phrases as a part of the propositions. Furthermore, it was observed that the concept maps showed a large variety in the number of propositions and structure. Students' concept maps do not include crosslinks. The use of crosslinks could be considered as options for experts. Students should be considered as novices in concept mapping. Most students indicate no arrows in their concept maps.

Students use different concepts as starting point of the concept map: BEHAVIOUR, OVERTRAINING, STRESS, and WELFARE. The differences between the valid concept maps of the first and second practice are merely context bound. In general, we concluded that the technical quality of the students' concept maps is weak, and the process of concept mapping should be improved. It is supposed that the weak quality of the concept maps is caused by a lack of experience in concept mapping by teacher and students. It could be supposed that increasing the technical quality of concept maps also further increases the students' conceptualization. As expected, the evaluation of the technical quality of the concept maps provides no clues for the understanding of students' conceptual development.

Considering the domain-specific quality of the concept maps, we found that because of a missing linking phrase, an incorrect proposition could be multi-interpretable. In addition, students use concepts from outside behavioural biology or 'translate' behavioural biology concepts in their own words. It appears that students that constructed a technical correct concept map, used different relation types. It seems that students reflect on the concepts of the practice in the construction of the concept maps, instead of creating 'the big picture' of behavioural biology.

Furthermore, it appears that students are able to relate the concepts correctly. The concept maps show a large diversity in the number of propositions and the individual student elaborated an average of 59% of the classifying concepts in a concept map. Furthermore, the analysis of the domain-specific quality of concept maps shows that students have a satisfactory understanding of the behavioural biology concepts, in particular STRESS and the STRESS MECHANISM. For most classifying concepts the amount of correct propositions is above 80%, which is high. Therefore, it could be concluded that the domain-specific quality of the concept maps is sufficient to evaluate the students' understanding of the behavioural biology concepts. The analysis shows that most students are able to relate behavioural biology concepts adequately. In addition, it could be expected that students' conceptualisation increases further when the construction process of concept maps is improved.

Knowledge transition through recontextualising

Concept maps also support the third component of conceptual development, construction. After two occurrences of using concepts maps as a reflection tool, concept mapping is used in the third practice as a construction tool, preparing students for writing an essay about human aggressive behaviour. Therefore, we investigated the relationship between the domain-specific quality of the concept map and the essay. The quality of the constructed concept maps is determined by the use of behavioural biology concepts, perspectives, and the use of linking phrases. We concluded that the better the domain-specific quality of the concept map, the better the essay that students wrote from a behavioural biology viewpoint. Less coherence between concepts is observed, because of the missing linking phrases between concepts. Consequently, we conclude that students can make a high quality concept map when they understand the meaning of and connections between concepts. Students' understanding of behavioural biology concepts increases when they are constructing a concept map. In scheme:

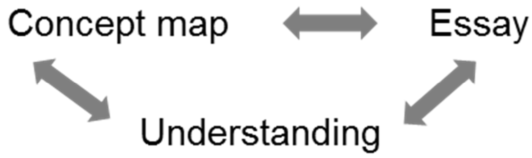

Figure 48. Scheme of the interaction between students' understanding, concept mapping and essay writing

Therefore, it appears to be important to pay attention to an adequate construction of concept maps. Nevertheless, we also can conclude that the LT-strategy for behavioural biology, consisting of several practices, invites students to recontextualise their knowledge, and results both in qualitatively inferior, and superior concept maps.

Adequate reflection and knowledge construction tools, such as concept maps and essay writing, should provide for transition of knowledge. This means that acquired knowledge in one educational practice is adequately (functionally) used in another educational practice. In a test-practice, students wrote essays from the behavioural biology view as a recommendation to the police for preventing riots. The analysis of the behavioural biology perspectives in the essays shows that nearly 80% of the students applied 1 or 2 perspectives (causation, function). The perspective of the development of behaviour is underexposed. The 20% of students who did not use perspectives did not adequately follow the instruction of the assignment.

Furthermore, the results showed that students are able to argue from the view of a behavioural biologist. Students used most behavioural biology concepts correctly. An exception is the understanding of the concept FUNCTION. In addition, NATURAL BEHAVIOUR is occasionally understood from the view of ‘what is normal'. Riots are not normal. In addition, the change of level of biological organization, from the organism to the population, seems not to be problematic.

Recontextualisation is a necessary condition for correct execution of the essay assignment, and it could be concluded that the LT-strategy provides opportunities for recontextualising, although not with all students. Considering the construction of the concept maps and the essays, it appears that the process of the construction of a concept map and the final essay depends on prior knowledge, context, and the constructed understanding. It seems that the more meaningful connections a student can show in the concept map, the better s/he will execute the writing assignment.

Furthermore, it is clear from the analysis of the essays that vwo students show more arguing than havo students. Vwo students also use behavioural biology concepts adequately, while students at havo level argue from a practical viewpoint with a minimal use of behavioural biology concepts. A problem had to be solved, so havo students note the causes of riots that they could find and formulate a solution. Vwo students also use resources about aggression in addition to the given resources in the workbook, such as the Wikipedia encyclopaedia. These observations could evoke the question whether an essay is an adequate manner to recontextualise for havo students. Generalizing, we could question what kind of actions drives students to recontextualise, because in both vwo and havo are students who did not recontextualise. Maybe the answer to this question could be found by looking to the opposite question: what obstructs the students' recontextualisation process? Based on the analysis of the essays, we distil the following possible obstructions:

1. The influence of the steering question of the assignment. In the last research cycle the steering question of the assignment was: ‘How to prevent such battles?’ Because of the link that is laid between the problem (preventing riots) and the role of a behavioural biologist, this question could be better replaced by the question: "What would a behavioural biologist recommend when we would ask him what could be done to prevent football riots?"
2. Several students argued only with the arguments they found in the given sources, which makes demands as to the selection of sources. A teacher who composes his/her own lesson material should foresee which possible answers could be derived from the selected sources.
3. Four students showed a rich fantasy and did not think about behavioural biology concepts anymore. Did they not understand the assignment? Or, was it a practical problem of starting (too) late with writing the essay? Is it due to the unfamiliarity of this kind of learning activity?

Learning objectives

In this chapter, we have compared the actual learning outcomes with the learning objectives 1-5 by analysing the students' understanding of the concepts of behavioural biology. Students' awareness of behaviour is the main goal of the scenario that is divided into 7 learning objectives. Students are able:

1. to explain that behaviour is caused by internal and external stimuli,
2. to describe that behaviour is the result of the relation between the organism and its environment,
3. to determine the function of behaviour,
4. to describe the development of behaviour,
5. to recognize the stress mechanism in the behaviour of humans and animals,
6. to carry out a simple behavioural research (only at pre-university level),
7. to discuss applications of behavioural research.

We finally conclude that the conceptual development of students resulted in understanding of the behavioural biology concepts. Students do not distinguish the different perspectives explicitly, but do correctly use the behavioural biology concepts. This LT-strategy for behavioural biology provides opportunities to recontextualise, although some improvements are desirable. A remarkable observation is that some students recontextualise, while others do not.

Summarizing the described conceptualization, students understand stressors as (internal and external) stimuli on which an organism has to react to survive (learning objective 1, 2, and 3). They know that this reaction consists of three types of behaviour: feeding, reproduction and defence. They understand that stress evokes in an organism when the environment is disturbed or unpredictable (learning objective 2), and that an organism reacts to acute stress through fight, flight, or freeze (learning objective 5). In case of chronic stress, an organism has to adapt, learning to cope with stress (learning objective 4, 5). Students can explain why cortisol and adrenaline are important hormones in regulating the stress mechanism (learning objective 5). Therefore, we conclude that students meet the learning objectives.

We should emphasize learning rather than teaching, and living, which is experiencing.
Richard Laki

10 Conclusions and discussion

10.1 Introduction

Our study aimed to find an adequate LT-strategy for behavioural biology. An LT-strategy for behavioural biology is elaborated in a scenario that describes the subsequent LTAs and hypothesizes the learning outcome. In chapter 9, we concluded that the conceptual development of students results in their understanding of the behavioural biology concepts. In addition, we have to evaluate the effectiveness of the LT-strategy, as demonstrated in the tested scenario. Therefore, answering the research question in section 10.2, we will conclude for an adequate LT-strategy. However, from the evaluation of the scenario in chapter 9, a few adaptations of the LT-strategy are proposed (section 10.3). Thereafter, when we conclude for the effectiveness of the LT-strategy, we also evaluate the design criteria (section 10.4). Furthermore, from the reflection on the design criteria, we discuss two didactical themes that have to be explored to improve the design of LT-strategies in biology education (section 10.5). Finally, we will consider the understanding of behaviour in the classroom in some final thoughts (section 10.6).

10.2 Answering the research question

Science is a never-ending story: scientific insights change, and new discoveries are made, so knowledge changes and multiplies. In current science education the problem of an overloaded curriculum is noticed, and in addition, students experience a lack of relevance and coherence of the knowledge they have to learn. Consequently, students' motivation to learn new knowledge is rather low.

From our prior research on the topic of behaviour in biology textbooks, we argued that the behavioural biology education in Dutch secondary education appears not to mirror today's scientific knowledge about behaviour. In addition, it lacks coherence, and does not lead to awareness of behaviour as a biological key concept. Therefore, a renewal of the curriculum for behavioural biology in Dutch secondary education is necessary, and we have formulated the research question: '*What are the characteristics of an adequate learning and teaching strategy for behavioural biology in secondary education that increases students' awareness of behaviour as a biological key concept*'. Adequate means sufficient to satisfy a requirement or to meet a need (American Heritage, 2009), without being abundant (Collins, 2003). Therefore, an LT-strategy for behavioural biology is adequate when it sufficiently meets the noticed problems of behavioural biology education, such as we described in chapter 1.

To answer the research question, we explored the question both from an educational viewpoint and from a conceptualizing of the concept BEHAVIOUR. From our view on learning and teaching, we argued for two educational approaches: the problem-posing approach and the concept-context approach

(section 2.4). These approaches include the formulated building blocks: the use of contexts, interaction, and motives. Considering the concept BEHAVIOUR, we explored both the scientific meaning, and the conceptions of behaviour in education in The Netherlands, the USA, and Germany.
This exploration resulted in eight design criteria for an LT-strategy for behavioural biology. In a cyclic process of design and data collection, we developed an LT-strategy that aimed to increase students' awareness of behaviour.

To investigate the LT-strategy for behavioural biology, we formulated a hypothetical LT-process that was tested in two subsequent research cycles, each consisting of 2 or 3 case studies. We demonstrated that the course of the scenario of the second research cycle proceeded as intended. To develop a central steering question, we found the importance of having a well-designed and well-documented focus lesson. In addition, this research underpins the importance of a non-interrupted storyline, and students' ability to recontextualise can be increased by using an interconnected sequence of practices. Furthermore, the main question whether students' awareness of behaviour through the LT-strategy is evoked can be answered with a resounding ‘yes’. Students adequately conceptualize the behavioural biology concepts.

Summarizing, the use of authentic contexts, interactions, and motives stimulates students' motivation, providing for relevance and coherence. Therefore, we conclude that an adequate LT-strategy for behavioural biology could be constructed with the concept-context approach and the problem posing approach.

10.3 Adaptations to the final LT-strategy

Although the results presented in chapter 9 showed that students understood the behavioural biology concepts, we suppose that the LT-strategy can be improved. In this section, we propose some improvements that could be undertaken.

Concept mapping as a reflection tool could be improved by improvement of the technical quality, as we concluded in section 9.4. Students must be guided to construct complete propositions by relating concepts through linking phrases. Another issue in the instruction is the systematic construction of concept maps. Therefore, an unambiguous steering question and an example, or a start of the concept map should be given. In this research, students had to make a glossary by themselves. Another option is the addition of a glossary of frequently used concepts in the workbook. In addition, the instruction for guidance of concept mapping should be included in the teachers' manual. Nevertheless, Yin, Vanides, Ruiz-Primo & Ayala (2005) indicated that if used as an assessment tool, the method of construction of a concept map by students themselves seems to be more effective than when the assignment has pre-selected linking phrases.
Students evaluate some texts in the *workbook* as too long. Therefore, the length, level, and language of the texts in the final version of the workbook and the learning materials have to be revised, particularly at havo level.

Furthermore, the LT-strategy should be adapted at two important points: the sequence of the LTAs in the (second) practice of the building of a welfare friendly pig stable, and in the third practice, as the scenario malfunctions in some places.

The pig stable assignment (second practice havo level)
The most important proposed improvement is a change in the sequence of the LTAs in practice 2a, designing a welfare friendly stable. In the second research cycle, the LTAs[7-9] (the design assignment) are placed at the end of the educational practice. Students have to learn first about natural behaviour of farm animals, and research the (chronic) stress of pigs. Although this choice is according to the basic concept map for behavioural biology (figure 14), the LTA[7-9] should be situated as the starting point of the storyline, because designing is the activity of the authentic practice. Then, a need to know about natural behaviour and research regarding (chronic) stress and welfare of pig evokes from the assignment. Furthermore, it should not occur that the assignment may be passed over when there is time trouble, as occurred in the class [2b_h]. In both the first and second research cycle students evaluated the design assignment as a motivating LTA.

Since students focus on the design instead of on behaviour, the question regarding the improvement of the scenario should be posed. The main improvement would be another sequence of steering questions, thus a change in the storyline. The current storyline is broadly shown in figure 49.

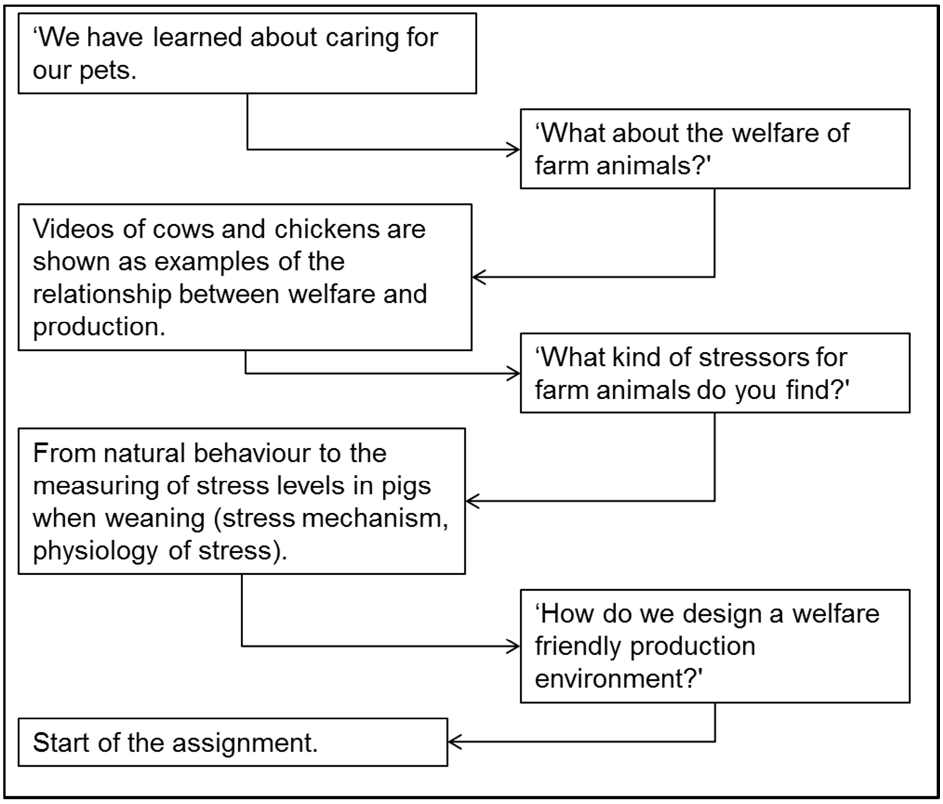

Figure 49. Executed outline of the sequence of steering questions (storyline) of the practice of the design of the welfare friendly stable (second research cycle).

The disadvantage of this sequence is that it is possible to avoid the assignment of designing, since from the LTAs[6.1-6.2] prior to this assignment, there is no need evoked for designing a welfare friendly stable. Therefore, we suggest a change of the sequence of LTAs starting with the activity of designing. The outline of the adapted sequence of steering questions is shown in figure 50.

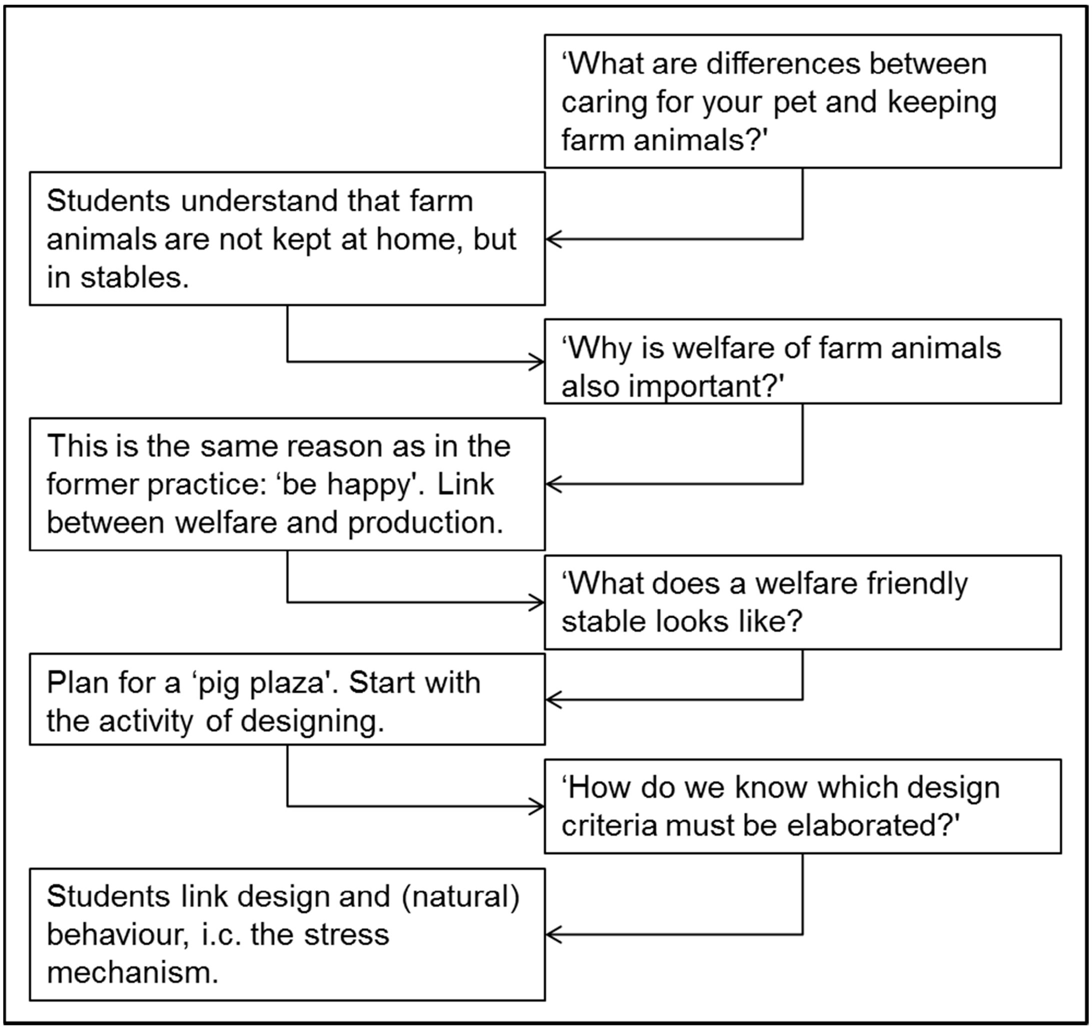

Figure 50. Outline of the adapted sequence of steering questions for the storyline of the practice of the welfare friendly stable design.

The use of design instructions (design cycles) is not necessary, because they are too complicated for students, and cost too much time. Accounting for natural behaviour is a design criterion for a welfare friendly stable. Therefore, designing requires a need to know about the natural behaviour of pigs, and their behaviour when they are stressed. The advantages of this sequence could be that less emphasis can be put on the design procedure, because of the link between design criteria for a stable and natural behaviour and stressors of pigs. In this way, deletion of the assignment of designing a stable is avoided.

Third practice of preventing riots

The third practice in the second research cycle was aiming to test students' knowledge about behavioural biology by writing an essay. This form of testing is not common in biology education, and

appeals to the creative thinking of students. The ability to recontextualise is an important condition for executing an assignment such as an essay. Although the video of the senseless violence of a child problematized aggressive behaviour, the change from practice 2 to practice 3 was not fluently prescribed. Sometimes, this obstruction was caused by the activities of the teacher that were not prescribed in the teachers' manual, or even caused by an interruption of the lessons by a vacation.
Another point of attention is that the change from the viewpoint of the behaviour of the child to the viewpoint of group behaviour in football riots seemed to be a change of practice, or in terms of this thesis, the video of the child could be seen as an embedded practice.

The third practice in the LT-strategy should contain a continuing storyline, guided by the problem posing heuristic of question-activity-reflection of the problem posing approach. From the data analysis in chapter 9, it is clear that concept mapping is an adequate instrument for learning to recontextualise, and should be part of an educational heuristic leading to a form of creative storytelling[31]. A possible heuristic is presented in figure 51.

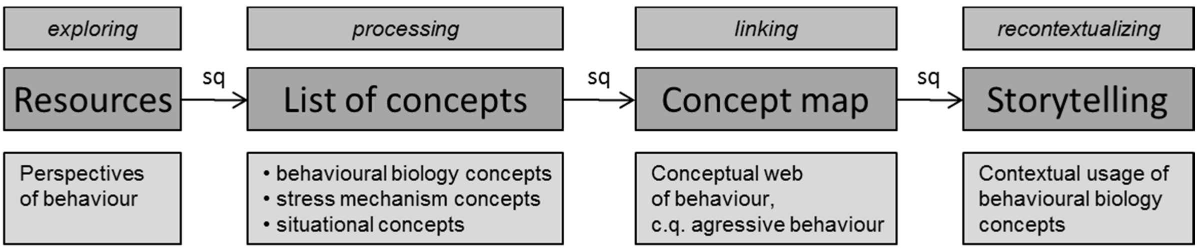

Figure 51. Possible didactical heuristic, leading to a form of storytelling. The first row presents transition of information into relevant knowledge. The second row stands for a basic form of an LTA, connected by steering questions (sq). Resources should contain relevant concepts, defined in the list of concepts. The third row is the current elaboration for behavioural biology education.

According to this line of reasoning, the outline of the scenario of the third practice could be adapted as presented in Figure 52, whereby the steering questions (sq) in the third column are the questions in figure 51. Furthermore, after exploring the concept AGGRESSION, students have to recontextualise when the population level is introduced. The introduction of the population level could mean an obstruction when students are not familiar with the concept POPULATION. Actually, they have to understand that the characteristics attributed to a population are not the same as the characteristics attributed to an organism.

[31] In addition to an essay, other forms of storytelling are probably possible, such as making a video, producing a play, creating a cartoon, etc. (Whatedsaid, 2010)

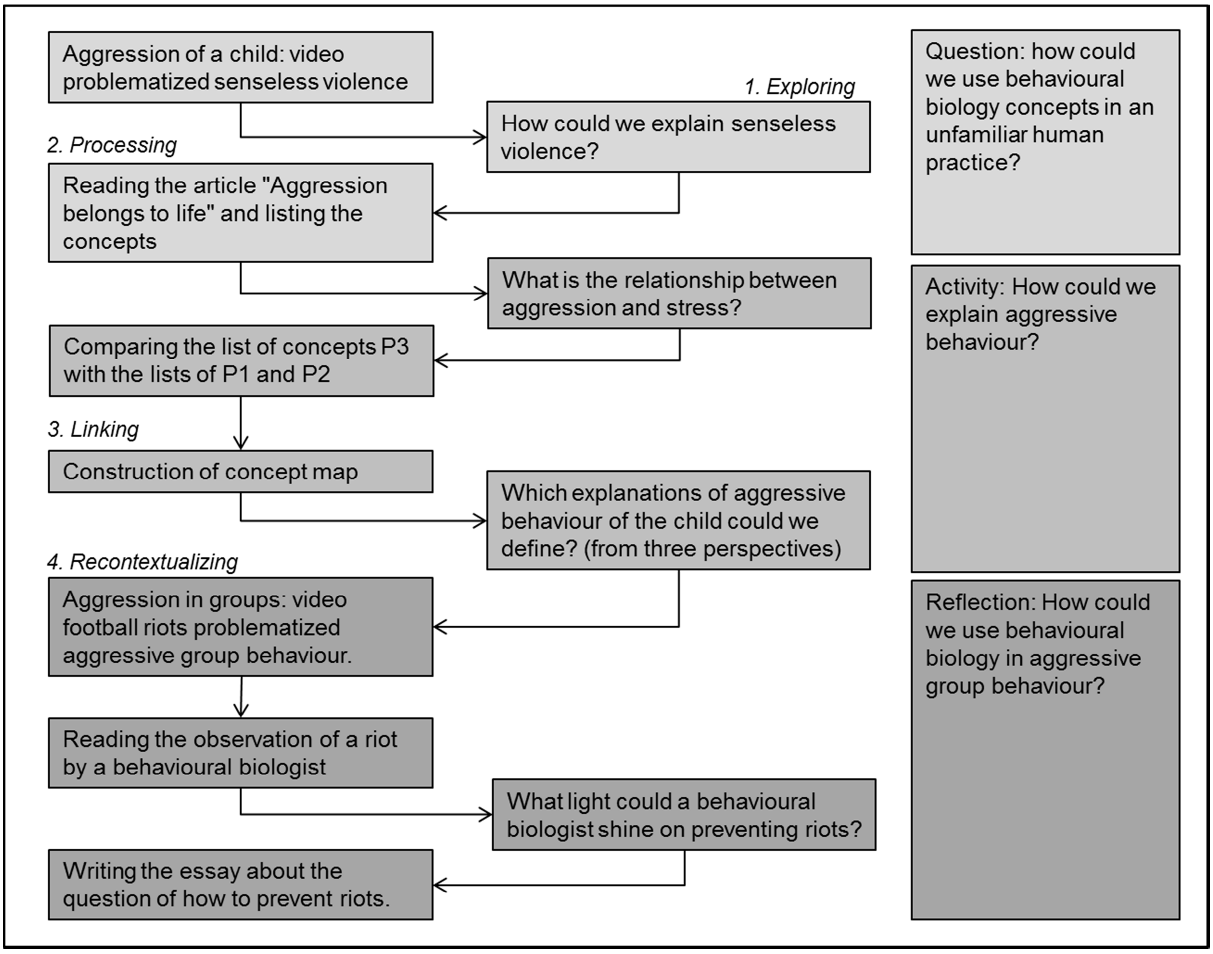

Figure 52. Improved outline of the LT-strategy of the third practice. The (test) practice is divided into three parts, indicated in the right column, whereby each part is a component of the problem posing approach. The numbers 1-4 are the components of the proposed heuristic of figure 51.

10.4 Evaluating the design criteria

In section 10.2, we concluded that the LT-strategy for behavioural biology is adequate, although improvements are possible (section 10.3). The LT-strategy is based on eight design criteria, and in this section, we will evaluate whether the design criteria have the expected didactical impact for learning and teaching behavioural biology. Do the research results underpin the correctness of our view on learning and teaching? In addition, which new didactical principles indicate for further research?

The design criteria 1-4 followed from our view on learning and teaching (chapter 2). The design criteria 5-8 were formulated from the conceptualization of behaviour as described in chapter 4. We evaluate the elaboration of the criteria in the strategy, and determine its usefulness in biology education.

From an authentic practice to an didactical appropriated authentic practice

1. An LT-strategy for behavioural biology should be based on behavioural biology concepts used in authentic *social practices*. Authentic means existing in social reality. The behavioural biology concepts should be elaborated and students should have the opportunity to explore their personal, societal, and/or scientific relevance.

The LT-strategy for behavioural biology consists of three educational practices that are based on authentic, existing practices. We found that the use of several practices meets the aim that students should have the ability to recontextualise. In addition, during the lessons we observed that both students and teachers relate the stress mechanism to humans, even when animals are the objects used in the activity of the practice, particularly in the practice about the overtraining syndrome. We also observed that students worked faster then was required and when questioned they explained they have interest in sport, or horses, or experiences with burnout. From these findings we concluded that students experienced that the practices were meaningful for them.

From the description of the selection and suitability of authentic practices for learning and teaching behavioural biology (see section 6.3.1), five criteria were determined, which can serve as general and practical notions for the selection of authentic practices in biology education.

1. What is the content demarcation of the subject that should be educated? What is (are) the aim(s)? What are the most important and relevant concepts to learn? Use these demarcation for developing a suitable educational practice.

2. Which levels of biological organization are concerned in the authentic practice? Exploring biological levels of organization is not only a need for behavioural biology education, but also common in other topics of biology (Knippels, 2002; Verhoeff, 2003; Westra, 2008), and the distinction of levels of biological organization is a condition for systems thinking.

3. How should the practice evoke the motivation of students? Answering this question, a distinction should be made between the educational approach and the authentic practice itself. In case of the approach, questions can be answered about the activities of the authentic practice activating students' thinking. In other words, is there a need for problem solving or a question to answer? Do the activities of the authentic practice have possibilities for designing LTAs wherein students collaborate? In case of the selection of an authentic practice, the question how the practice does make sense for students should be answered. Are the activities of the practice recognizable in the students' daily life? Do the practices have social relevance? In Vygotskian terms: can the practice be considered inside students' zone of proximal development?

4. How can complexity of the authentic practice be reduced? Two procedures are described. First, create a non-interrupted storyline of LTAs, and second, let students play roles, so they are part of the story.

5. How can authentic materials be made suitable for learning materials?
   - Search the internet for relevant articles, videos, and images.
   - Adapt articles on language, level, and length.
   - Connect articles through questions with the relevant concepts.
   - Ask researchers for (a selection of their) original data.

Although these five points may look like a heuristic, it could better be seen as an interactive process, wherein searching for selection and adaption of authentic practices and learning materials alternate.
Also Prins (2010), using authentic practices as contexts for learning in chemistry education, formulates selection criteria for authentic practices: (1) motives and purposes for modelling should be recognizable for students, (2) characteristic modelling procedure should be an example of a general modelling procedure, (3) students should be familiar with the subject and complexity, and (4) the experiments at school should be practical.
It seems that both sets of criteria have similarities. In essence, the criteria aim to connect the demands of a practice to the requirements for science education, whereby the main challenge in adapting an authentic practice into an educational version is located in the differences in subject knowledge between experts and students.

In biology education, teaching and learning about three practices in one LT-sequence are rare. Westra (2008) suggests in his thesis that it seems sensible to look for practices which are not too difficult to adapt for use in classroom and do not need a lot of explanation of context-based knowledge. That should plead for starting the sequence with a practice concerning students' everyday life. In our LT-strategy, the introduction of the practices did not only depend on the practice itself, but we used embedded practices to create a non-interrupted storyline.
Both Westra (2008) and we found that students sometimes felt uncertain about what to learn and what the final test should look like. Students were motivated for studying about practices, although they sometimes liked to have a ‘simple lesson’, which means a teacher who explains the knowledge that students have to learn. Similar to Westra, we think this is a matter of habituation, although times of classical explanation of concepts by the teacher remain useful. Self-evidently, an explanation should be triggered by a motive, for example by the question ‘How does the stress mechanism in the body work?’ Nevertheless, the role of the teacher in the learning process is an important issue, and we will discuss it in section 10.3.1.
Furthermore, students are unfamiliar with writing an essay as a test, and with this form of knowledge construction, students wonder what is good and what is not. An acceptable explanation for students should be that in the concept-context approach a practice is as a test, instead of the test as a practice. For students, it should be clear that the test is about the whole practice, consisting of more than one lesson.

Nevertheless, in contrast to students in the first research cycle, most students in our second research cycle were not surprised that the test practice was about a topic that was not taught, neither were they surprised about writing an essay as a test form. Naturally, in the second research cycle, more time was spent to explore the test practice, and students were acquainted with the topic before writing the essay. They evaluated the test-practice positively and understood its aim, as the following quotes illustrate:

"I need to become familiar to this idea of testing, but on the other hand, it seems better, because you think more about the topics." [2c_v, evaluation, Anne]

"I thought it was a good test, because you have to apply everything that you have learned." [2b_h, evaluation, Conny]

"More difficult than a regular test, because you must understand more than learning." [2c_v, evaluation, Arthur]

"Interesting, because you had to apply behavioural biology to our own people and step by step we can explain behaviour." [2a_v, evaluation, Joost]

Summarizing, the LT strategy fully meets the design criterion of using a sequence of authentic practices. The practices did have relevance for students, although the unfamiliarity with the approach did evoke some feelings of uncertainty. The five criteria for selection of practices clarify how practices can be selected in (biology) education. Finally, the results in using (educationally appropriate) social practices in education underpin our view on learning and teaching, so we are satisfied with the results of this part of the research.

Within an appropriated authentic practice

2. Participation in a social practice motivates learning as the outcome of *interaction* between a person and his/her environment. An LT-strategy for behavioural biology must promote interaction between learners and their learning environment in an educationally appropriate social practice.

The LT-strategy favours the students' conceptual development, as we demonstrated by the reconstruction and the judgment of the effectiveness of the *interaction* in the class discussions (see section 9.4.). Therefore, the LT-strategy for behavioural biology meets the second design criterion, underlining our view on learning and teaching.

Participation in a social practice should not imply a similar interaction of students in an educationally appropriate social practice. Because the kind of activity is different, students actually act in an educational practice concerning lessons about behaviour. For example, the activity ‘caring for your dog’ differs from the learning activity ‘discussing how to care for your dog’.

In the reflection phase, following the lesson series students should be asked whether they are able to care for a dog (do they know how to care a dog?). However, we concluded that the steering question of a practice is not explicitly answered, and the emphasis of the reflection was on the behavioural biology concepts.

Nevertheless, we feel, therefore we learn, and the possibility to be empathic with the practice, or to play a role within it, could stimulate students' affection. We found such statements in the students' evaluation when they wrote that it was nice to be involved in the lessons.

Students also interacted with the learning materials, particularly with the texts in the workbook. Students had to explore each text with a set of questions that were aimed to lead students' thoughts trough the texts and to get them pay attention to behavioural biology concepts. Considering the following evaluation quotes it is assumed that this aim was attained:

> "The answers for the questions posed in the book were acquired during the lessons and could not be copied verbatim from the text." [2a_v, evaluation, Daphne]

> "This method is better than the textbook. These were normal instructions, not copy-paste." [2a_h, evaluation, Frederik]

> "I am very pleased because I can highlight information and from there make the right answers. You have to explain everything from the text itself." [2a_v, evaluation, Joost]

Nevertheless, some students reported that they rather liked a 'normal textbook' and the 'old manner' of being taught, because they did not understand what they had to do, or what they had to learn. The following quotes are examples of these experiences:

> "I found the normal lessons better. The teacher explained somewhat and then I went to work. Now you are working all the time in classroom and then you have to do everything at home." [2b_h, evaluation, anonymous]

> "I do not have the idea that I am really learning". [2b_h, evaluation, Marleen]

Another student reflected that the workbook was chaotic to her. In addition, the lack of experience of students with these kinds of LTAs could make them uncertain, as we mentioned before. Did these students have trouble with eliciting information about behavioural biology from articles and videos? Indeed, the capability of abstract thinking determines at least to some extend the learning outcomes, and therefore reflection periods during the scenario are very important.

Summarizing, we conclude that the adaptation of the activity of an authentic social practice into learning activities in an educational practice is not problematic. However, a main condition is that the interaction 'touches students' affection' and that they get involved in the activity that is derived from the authentic practice.

Of course, students know they participate in an educational practice, learning behavioural biology, and not in caring for a dog, or designing a pig stable. Therefore, the design criterion 'the need for interaction' could be seen as a bridge between the first criterion (using authentic practices) and the next criterion, the use of students' motives.

Finally, we also conclude that the LT-strategy creates a learning environment that promotes interaction, which meets the second design criterion.

3. Learning activities must promote the thinking processes of students. Therefore, an LT-strategy for behavioural biology must evoke *motives* or one or more steering questions. The sequence of LT activities must provide a storyline and create opportunities for non-interrupted learning.

Two kinds of motives could be distinguished: cognitive motives that are directing students' thinking, and the affective motives creating a drive to know more. A central steering question is an example of a cognitive motive, while the relevance of the first practice – a life world practice – can be seen as an example of an affective motive for learning. Both kinds of motives elicit students' motivation to learn.

The lesson series appears to increase students' motivation for the subject, and the kind of learning activities (the didactical approach) added to the engagement of students, as we found in their evaluation forms for the lesson series. Students reported on two perspectives about the lesson series: on the perspective of the *approach* and on the perspective of the *practices*. As Stijn and Angela wrote:

"I found, frankly, the subject itself not very nice, but the way we were taught was fun. The method I think is clear. And later I found it more interesting and more fun." [2c_v, evaluation, Stijn]

"It is very convenient. You are more motivated to participate by the interesting subject and teaching methods. [2b_h, evaluation, Angela]

More in detail, reflecting on the *approach*, students refer to collaboration in the LTAs, the degree of acting by themselves, the use of videos, and a clear workbook with clear questions as remarkable educational characteristics of the approach. This conclusion is illustrated with the following quote:

"Information that let you think." [2a_v, evaluation, Tom]

Some students related to the manner of teaching with the expected learning outcomes, as shown below:

"Very nice, through the way we worked in groups and because the subjects were always repeated, I remembered it better." [2c_v, evaluation, Robert]

"(...) But maybe, you learn it better, because you're doing more." [2c_v, evaluation, Michelle]

"You recognize things in everyday life that we have discussed in class." [2a_v, evaluation, Claire]

The main conclusion from students' opinion about the used *practices* is that they like them when they have interest in pets, horses or human beings. Naturally, that is what we expect, because pets are relevant for most of them, and underline the use of authentic practices in education. However, some remarkable quotes illustrate not only students' interest, but also support the argument for meaningful learning when the same concepts are used in different practices.

"I found everything interesting, but my ranking is: 1. People, 2. Pets (dogs), 3. Farm animals." [2a_v, evaluation, Annelot]

"I liked to compare the three different subjects, but I liked man the best, because it is closest to us." [2a_v, evaluation, Iris]

"I found pets and people funny. Farm animals I found a little less. It fit well with the subject. [2a_h, evaluation, Milan]

"Fun, these are subjects that you see in everyday life too. (...)". [2a_v, evaluation, Jan]

"Very interesting. I have no pets myself and no contact with farm animals, so I learned something new." [2a_v, evaluation, Yi Ming]

The practice about the overtraining syndrome is perceived as boring. This is probably caused through the assignment about behavioural research, because students have to observe the behaviour of horses for 15 minutes. Therefore, ‘nice’ also depends on the LTA that has be executed. Students have also made some critical notions about the practices, in particular when they are interested in humans. As Rianne wrote:

> "We stayed very long on the dog. I would have preferred to focus on human behaviour." [2a_v, evaluation, Rianne]

Alternatively, in the words of another student:

> We have briefly talked about people, while I think that humans are more important than dogs or livestock. [2b_h, evaluation, anonymous]

Furthermore, as we concluded from the first research cycle, students' motivation also elicits when an educational appropriated practice is in the students' zone of proximal development, meeting the correct profoundness. We adapted the scenario with the introduction of the physiology of the stress mechanism and a scientific practice at vwo level. On the other hand, in the second research cycle students complained rarely about the level.

However, evoking students' motivation goes further than the construction of affective motives. We also found that the LT-strategy promotes students' thinking processes on behavioural biology concepts by using the problem posing approach as a didactical framework for evoking motives.

From the focus lesson in the first research cycle, we learnt the importance of evoking the central steering question ‘why do they do that’. In the focus lesson in the second research cycle a framework for learning and teaching the three perspectives is incorporated. In section 6.5 we argued for a coherent conceptual framework - a non-interrupted storyline -, because the three perspectives are sequentially ordered, and not hierarchically. Therefore, we found that the focus lesson provided for a ‘horizontal’ structure of the concepts, additional to the development of the central steering question. The horizontal structuring of the perspectives is most visible in the use of the problem posing approach in the first practice, as we have shown in figure 21. Notice that the phases five and six (reflection) are not indicated in the figure, evidently because the figure concerns the behavioural biology concepts, while the reflection concerns the steering question of the practice. However, speaking about the steering question of the practice, we found that there was an inconsistency in the reflection LTAs. For example, the steering question of the first practice is how to care for your pet. Therefore, the reflection should include an answer on this question. However, in the reflection, in the learning material the assignment is introduced with the statement that students are going to explore what they learnt about behaviour. In addition, the title of the concept map has the steering question on how to explain behaviour. Nevertheless, we found that the concepts that students included in the concept maps reflect the context, which might be expected. Therefore, the impact of the fore-mentioned inconsistency is limited and it is questionable if the effect of the reflection phase on conceptualization could be reinforced when inconsistency is avoided.

As we found in the former chapter, in the practice of designing a welfare friendly stable, an adaption of LTAs in the scenario is needed to increase the relevance of this practice for students. In the second research cycle, the steering question of the practice is not developed at the beginning of the practice, but later on. It seemed not to have resulted in a limited conceptualization. However, the chain of motives can be improved, as we described in section 10.3.

The problem posing approach within the LTAs is restricted to a 3-step approach: Question – Activity – Reflection. Most LTAs are simple assignments, requiring a simple approach. Nevertheless, simple does not mean without meaning and each step in the approach has to be taken. Particularly, we emphasise the importance of the reflection, because it can serve as the next step in eliciting a new motive. Nevertheless, it appears sometimes that the teachers forgot to evoke a new motive for learning.

Prins (2010) reported a need for guidelines for evoking *reflection* by students themselves. We agree with this conclusion. Although reflection phases are self-evident when using the problem posing approach, the competence to reflect on what should be learnt ought to be developed. Guidance of students' reflection starts with answering a steering question, and a point for improving the scenario is to increase the coherence between the steering questions of subsequent assignments. In the second research cycle, students noticed different steering questions for concept maps. Such steering questions are implicit, because in classes [2a] and [2b] no steering question is asked in the learning materials[32]. Students [2c_v] have defined a steering question themselves. Although a link between the list of concepts and the concept map could be supposed, the concept maps of class [2c_v] show that students have formulated different steering questions:

"How can aggression be explained?" [2c_v, cmap P3, Thomas]

"What is the cause of aggression?" [2c_v, cmap P3, Manon]

The steering question of Manon is restricted to the cause of aggression, while the steering question of Thomas also asks for other explanations than for causes. Different steering questions will result in different concept maps.
Furthermore, the third practice is the reflection phase of the whole scenario. From the construction of the concept map to the essay writing is a next step wherein students have to change their mind from explaining aggressive behaviour to thinking about preventing riots. The linking chain is the role of the behavioural biologist, and as we suggested before, the steering question of the essay could have been one of the obstructions. Therefore, in section 10.5 we discussed an improvement of the third practice.

Summarizing, the elaboration of the problem posing approach in the LT-strategy appeared to be effective. Two obstructions were noticed. First, in the concept maps, students use different steering questions, and second, the subsequent motives in the practice of designing a stable could have been more logical to form a non-interrupted storyline.

Nevertheless, we concluded that the LT-strategy fully meets the third design criterion, and, in addition, we found that the execution of the scenario was mainly non-interrupted.

[32] Only in the learning material of class [2c_v] students have to answer the question: “to which central question does your concept map give an answer?”

From one appropriated authentic practice to another

4. *Recontextualising* of earlier acquired concepts is not self-evident when other practices are introduced, and should be incorporated explicitly in the LT-strategy. This implies that an LT-strategy should consist of more than one practice.

Transition is the capability of a student to adapt his or her understanding to another practice, and this process requires recontextualisation. We found that the students recontextualised the behavioural biology concepts when they wrote an essay. It appeared that for the construction process of an essay, prior knowledge, context, and the constructed understanding were necessary conditions. It seemed that the more meaningful connections students show in a concept map, the better the essay they wrote.

Considering the use of three practices the LT-strategy meets the fourth design criterion. However, to evaluate the design criterion we have to question whether this criterion is effective. To what extent did students learn to recontextualise? In section 9.5 we defined recontextualising as the result of the didactic approach, the concept-context approach, including adequate reflection phases. Nevertheless, it would be recommended to search for the process of recontextualising itself. How did students understand the context, and the meaning of a concept in this context, and how did they adapt it to another meaning of a concept in another context? Anyway, more research on recontextualising should answer the question of how to approach to this problem.

Behavioural biology

In chapter 4 we reviewed 21st century behavioural biology, resulting in four design criteria for an LT-strategy for behavioural biology. We characterised contemporary behavioural biology, first, as a dynamic field with crosslinks to other biological disciplines, and second, (the development of) behaviour as a more complex and dynamic process, requiring systems thinking. Third, behavioural biology is characterised by the structuring of four explanatory perspectives: causation, function, development, and evolution. In addition to these characteristics, behaviour always has (social) relevance, since ‘no behaviour’ does not exist. This relevance can be recognised in the aims of behavioural biology. Design criteria 5-8 deal with behavioural biology.

5. An LT-strategy should be based on *21st century* behavioural biology, which means at least that *links* must be elaborated with other biological disciplines such as physiology, genetics, and psychology.

With respect to the work of ethologists, Tinbergen, Lorenz, and Pavlov, behavioural biology should not be taught from a historical viewpoint (as we have argued in section 4.2). The LT-strategy for behavioural biology presented in this thesis meets the design criterion of being based on 21st century behavioural biology: first, by the use of contemporary authentic practices, and second, by the links that are made with physiology, and implicitly with psychology when exploring the concepts STRESS and AGGRESSION. A few remarks are made.

1. When Levitis, Lidicker, & Freund (2009) proposed a definition of the concept BEHAVIOUR, the lesson series was already designed. Awareness of behaviour is not the same as understanding behaviour, and

it could be expected that the awareness could increase when students understand the definition of behaviour. Behaviour is about the interaction of the whole organism or population with its environment, and systems thinking competence should increase the understanding of the definition. However, evaluating design criterion 6 about systems thinking, we indicated that systems thinking competence is not explicitly incorporated in the scenario. Therefore, in section 10.5, we will argue how systems thinking can be embedded.

2. Behavioural biology is a broad discipline, which means that a selection must be made for educational purposes. Although the use of links with other biological disciplines is a design criterion, not many crosslinks could be indicated in the available lesson time. Physiology and psychology are the most self-evident disciplines. Because of the relationship between hormone levels and behaviour, with physiology another biological level of organization is introduced. Psychology deals with social relevance of behaviour in students' life.

3. Although the link between genetics and behaviour is unquestionable, in the LT-strategy for behavioural biology heredity is seen as a subordinate concept within the perspectives of causation and development, because genes do not cause behaviour, but code for proteins. Despite popular statements that link genes to behaviour, in our prior research we found that students did not distinguish nature from nurture. In addition, in the execution of the scenario we did not observe confusion about the role of genes, probably partly because the emphasis is on hormones and not in genes. Nevertheless, the controversy nature-nurture seems to have been changed to a controversy between quantitative behavioural geneticists and developmental psychologists (Griffiths & Gray, 2005; Griffiths & Tabery, 2008). However, disputes on the philosophy of biology are generally not sensible for students in secondary education.

4. In addition, in the lesson series both disciplines physiology and psychology are integrated in the elaboration of the General Adaptation Syndrome. This was intended to provide for coherence in the web of behavioural biology concepts. In addition, the stress mechanism is an excellent model for the introduction of the molecular level of biological organization, and we found that students are able to switch in dealing with one level of biological organization or another. Although it was not deliberately indicated in the scenario, elaborating the stress mechanism is an example of the so-called yo-yo strategy (Knippels, 2002). Figure 53 shows a scheme of this yo-yo strategy for the stress mechanism; the scheme could be seen as a model of the first practice.

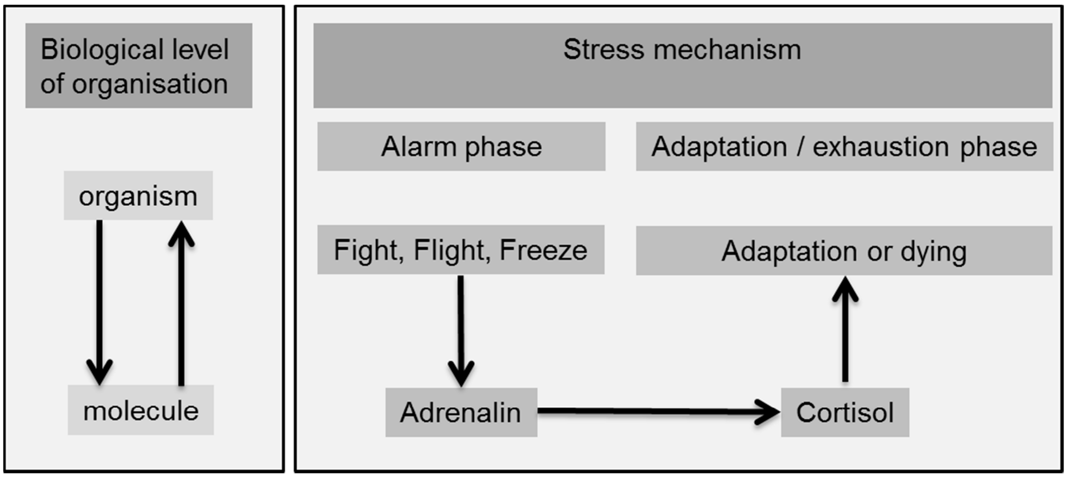

Figure 53. Model for the stress mechanism, according to the yo-yo learning and teaching strategy.

The stress mechanism is used in psychology as well, although sparsely, as we found in the approach from two psychologists, wherein they teach people to thrive in the demanding pressures of everyday life (Skeates & Fabrin, 2010). We observed that the stress mechanism provides the same social relevance for students. Therefore, looking backwards, we are satisfied with the embedding of the stress mechanism into the LT-strategy, as an indispensable link in 21st century behavioural biology education.

6. Students should be *aware* that behaviour emerges in a dynamic and *complex system*, which results from multiple causes and develops through the interaction of the organism with its environment. Therefore, an LT-strategy should emphasise *systems thinking* to achieve awareness of behaviour and coherence between concepts.

Are students aware of the dynamic and complex nature of behaviour? The answer to this question is simply that we do not know, because, in retrospect, the LT-strategy only implicitly provides for the systems thinking competence as a tool for attaining awareness of the emergent nature of behaviour. Systems thinking is required in particular to acquire an appropriate understanding of the General Adaptation Syndrome. In the stress mechanism different levels of biological organisation are involved. In chapter 9 we concluded that the LT-strategy emphasises students' awareness of behaviour. In chapter 6, we argued for the use of concept maps to create coherence, whereby figure 14 and figure 15 showed examples of the construction of a concept map on behavioural biology concepts. However, systems thinking is more than creating a coherent web, and recognising that behaviour is emerging in a dynamic and complex system differs from the construction of concept maps. Therefore, the question that also should be answered is which adaptations of the LT-strategy are required to include systems thinking explicitly? However, considering that students' awareness of the scientific explanation of behaviour at the beginning of the lessons series is rather limited, it is questionable whether the LT-strategy for behavioural biology could be adapted accordingly within the available lesson time (12 lessons).

Summarizing, we conclude that the LT-strategy for behavioural biology does not fully meet the sixth design criterion, by not explicitly emphasizing systems thinking. In section 10.5, we will attempt to construct a didactic approach for systems thinking in teaching and learning of behavioural biology in secondary education.

7. The behavioural biology concepts in an LT-strategy should be *structured* according to the perspectives of causation, development, function, and evolution of behaviour.

In his famous essay Tinbergen (1963) structured behavioural biology with four questions regarding the explanation of behaviour. With the exception of the question about the evolution of behaviour, we transformed these questions into perspectives on behaviour that students have to use in the exploration of the educational practices on behaviour. From chapter 9 it appears that students are able to distinguish the perspectives on behaviour: function, causation, and development. Therefore, the LT-strategy for behavioural biology meets the learning objective that students should be aware of behaviour. In addition, the LT-strategy could be also consistent with the biological key concept of evolution. Indeed, adaptability is probably the most distinctive characteristic of life (Selye, 1978). Nevertheless, in order to consider the evolution of behaviour students have to understand the concepts EVOLUTION and NATURAL SELECTION. If evolution is adequately learned and taught it would not be a problem to explore the evolution of behaviour. However, the concept EVOLUTION must be carefully taught (Demastes, Settlage, & Good, 2006), and it is not recommended to use the topic of behaviour for the introduction of the concept EVOLUTION.

8. An LT-strategy should pay attention to the social *relevance* of behavioural biology in order to develop students' understanding of its relevance.

In table 4 we indicated the concepts explicitly showing the social relevance of behavioural biology: WELFARE, NATURAL BEHAVIOUR, STRESS, CONSERVATION OF SPECIES, EXTINCTION, HABITAT LOSS, and UNDERSTANDING OF HUMAN NATURE. Because of the practices that were selected, the concepts CONSERVATION OF SPECIES, EXTINCTION, and HABITAT LOSS were not included. However, it is supposed that there are social practices, such as the zoo, to elaborate in order to meet the social relevance of behavioural biology in the conservation of species. The other concepts are embedded in the selected practices, and although the aims of behavioural biology are not explicit, students understand the concepts WELFARE, NATURAL BEHAVIOUR, and STRESS very well, as we demonstrated in section 9.4. Summarizing, we conclude that the LT-strategy for behavioural biology meets the design criterion of the social relevance of behavioural biology.

Finally, we conclude that the LT-strategy meets all design criteria, with the exception of the design criterion that an LT-strategy for behavioural biology should emphasise systems thinking competence.

10.5 Some didactical implications for biology education

Taking everything together, two didactic themes seem to be important for further exploration because of their implications for biology education. First, because a didactic approach is a tool for the teacher, we have to consider the role of the teacher. Learning is the outcome of interaction, and the role of the teacher is part of the LT-process. In section 9.4 we demonstrated that teachers differ in the use of the strategy, with implications for the LT-processes. Therefore, in section 10.5.1 we consider the role of the teacher related to the utilized didactic approaches.

The second theme is the development of a systems thinking competence. We found that the LT-strategy for behavioural biology did not emphasise systems thinking competence, and in section 10.3.2 we argue for an approach for the development of systems thinking in an LT-strategy for behavioural biology.

10.5.1 Considering the role of the teacher

Although the teachers' role is not the subject of this research, considering the interaction in the LT-process as described in chapter 9, we also observed the role of the teacher. From the execution of the first research cycle, we found that explaining the didactic approach and using a teachers' manual were necessary conditions in the second research cycle. Nevertheless, in the second research cycle, we observed that some teachers stayed close to their own manner of teaching, guiding the students' conceptual development by explaining instead of by questioning, while other teachers improvised instead of using the teachers' manual. Reasoning in line with our view on learning and teaching (chapter 2), we consider education as a social practice wherein a teacher (subject) uses didactic approaches to foster the learning process of his/her students (object). In line with behavioural biology, learning is a developmental process that emerges from the interaction between a learner and its environment. The quality of the teacher is probably the most important factor in that environment (Wiliam, 2010). Therefore, we suppose that the teachers' capability to use the didactic approach in the LT-strategy could be improved.

In addition, three other reasons to pay attention to the role of the teacher can be noticed. First, in this study much of the instruction of the teachers on the didactical approach is provided by the researcher. However, such an amount of instruction is unusual in teaching practice, and generally, teachers only have a teachers' manual. Second, in the Netherlands there is no educational culture of teachers designing their own lessons, but rather of following the textbooks. So, creating a non-interrupted storyline is unusual, as is teaching functional knowledge (see chapter 2). Third, it took a lot of time to prepare and construct the lesson series on behavioural biology, and it is questionable if teachers could effectively construct lesson series using the indicated didactic approaches.

Summarizing all observations, we recognise three problems. First, teachers sometimes improvised in handling the scenario, because of the need for class management. One teacher experienced the scenario as an uncomfortable feeling straitjacket. Positively posed, the cause of the problem is possibly that the teacher could not adopt the required teaching style. Second, teachers were not as familiar with the behavioural biology concepts as they should have been in order to teach adequately. Third, teachers had difficulties with understanding the didactical approaches, particularly the requirement to create a non-interrupted storyline.

Actually, we could consider the following two issues concerning the role of the teacher: 1) what is the influence of teaching styles, and 2) understanding how teachers could construct a non-interrupted storyline, using the concept-context approach. We will elaborate both issues.

Just as students have an individual learning style or preference, teachers practice teaching styles that suit them. From the literature, there seems to be not much agreement about the definition of a teaching style (Grasha, 1996), and it often appears that no distinction is made between pedagogical and didactical approaches. Although it is self-evident that pedagogics and didactics interact, we prefer to make a distinction between these two disciplines, because of their roles in teaching and learning processes. Pedagogical approaches tend to influence the (affectual) context of learning (the art of education), while the didactical approaches influence the learning process itself (the art of teaching). Therefore, we consider a teaching style as belonging to the didactics, and we could define a teaching style as a teachers' preference for a learning style.

Considering the students' conceptualization as described in chapter 9, we adopted the distinction Ruijters (2006) made, namely between interaction, reflection, and construction as components of conceptual development. Furthermore, Ruijters considers these three components as one end of the dimensions of thinking habits, which means that one could have more or less a preference for a constructive manner, an interactive manner, and a reflective manner of thinking. On the other end of the dimension are a conformistic, an intra-active, and a reproductive thinking habit. From the former chapter, we could understand that the LT-strategy for behavioural biology favours thinking habits of interaction, reflection, and construction. That could mean that a teacher who has opposing thinking habits is less able to teach behavioural biology according the LT-strategy for behavioural biology. If the reasoning is extended, students with opposing thinking habits could also have problems with the lesson series.

Additionally, in line with the findings of e.g. Knippels (2002), we subscribe the importance of the reflection phases in the LT-strategy as a part of the conceptualization. Therefore, teachers should understand how to reflect. Le Cornu & Peters (2005), describing the role of the reflective teacher, identified four strategies: developing reflective attitudes in students, explicitly teaching metacognitive skills and processes, making space for reflection in the classroom, and using and encouraging a responsive interaction style. Teaching and learning is an interactive process, and the last strategy emphasises that the teachers' behaviour must be appropriate to the students' thinking habits and learning preferences.

Different learning preferences of students require a design of an LT-strategy emphasizing different learning preferences. For the actual LT-strategy for behavioural biology, we estimate that it favours in particular such learning preferences as ‘exercising’ and ‘exploring’. Therefore, the next question could be how to adapt the LT-strategy so that it satisfies different kinds of learning and teaching preferences, such as learning by acquisition (Simons & Ruijters, 2008). We will not further discuss the supposed relationship between learning and teaching preferences here. Nevertheless, the question regarding the influence of teaching styles (the role of the teacher) on the execution of the scenario is an interesting question to explore.

The next issue concerning the role of the teacher we would consider is how teachers could easily integrate context and concepts into a non-interrupted storyline. To construct a non-interrupted storyline a teacher must understand the scientific concepts involved. In our view on learning and teaching (chapter 2, figure 3) we described the difference between spontaneous concepts and scientific concepts. Spontaneous concepts are developed in every-day-life learning, beginning in the concrete phenomena, while scientific concepts are developed in school learning (Wellings, 2003) (see section 2.4). In bringing school learning and every-day-life learning together in the concept-context approach, a teacher should master the abstract definition of concepts in mind and to be able to deal with the contextual (every-day-life) meaning of concepts. Therefore, the concept-context approach requires from the teacher that he is able to develop in a stepwise way the selected scientific concepts from students' prior knowledge. Consequently, we suppose that the observation of the teachers' inability to use scientific concepts in a practice is due to their incapability to switch between the different meanings of a concept. Kinchin & Hay (2000) report that concept maps produced by teachers as part of their preparation may be helpful in reinforcing the conceptual links that they need to make explicit to their students if they are developing an integrated knowledge structure. Nevertheless, solving this problem is not only a matter of experience with the concept-context approach, or a matter of preparation, but also a matter of the teachers' ability to switch between the different meanings of concepts. Construction of a concept map will be helpful in the development of this competence.

10.5.2 Systems thinking in learning and teaching behavioural biology.

In section 10.4, we concluded that the LT-strategy for behavioural biology does not instruct for using systems thinking, because the focus lay on creating a coherent web of behavioural biology concepts. Nevertheless, to understand the dynamic and complex nature of behaviour, the step from the construction of coherence to systems thinking should be taken. Therefore, in this section, we will explore a didactical approach for learning and teaching of systems thinking in behavioural biology in secondary education.

Systems Biology and Systems Thinking.

Although systems theories have been developed for more than 60 years, we now live in an exciting period in the science of biology, because of changing insights (Trewavas, 2006; Noble, 2008). Among others, the plasticity of the brain and the explication of genes influenced by environmental factors do raise the awareness that we need to understand complex systems.

Therefore, an important characteristic of this new period is the change from uncovering the working of components of a (biological) system to the interaction between those components. Such as Griffiths & Gray (2004, p. 2) formulate:

> "The fundamental unit that undergoes natural selection is neither the individual gene nor the phenotype, but the life cycle generated through the interaction of a developing organism with its environment."

In this view, development is understood as the emergent product of many decentralized and local interactions that occur in real time (Smith & Thelen, 2003).

Systems biology is the study of systems of biological components, which may be molecules, cells, organisms, or entire species and ecosystems. Living systems are dynamic and complex and their behaviour may be hard to predict from the properties of individual parts[33]. Biological systems are approached as networks of molecules, cells, tissues, organisms and populations that interact in time

[33] https://sysbio.med.harvard.edu/ (Retrieved November 2011)

and space. From the Life's Complexity Pyramid (figure 54), we actually could learn that interaction deals with information processing.

Eventually, Systems Biology should result in the full understanding of complete biological systems, including man[34]. Therefore, Systems Biology is addressing the greatest challenge of 21st-century science: the understanding biological complexity[35].

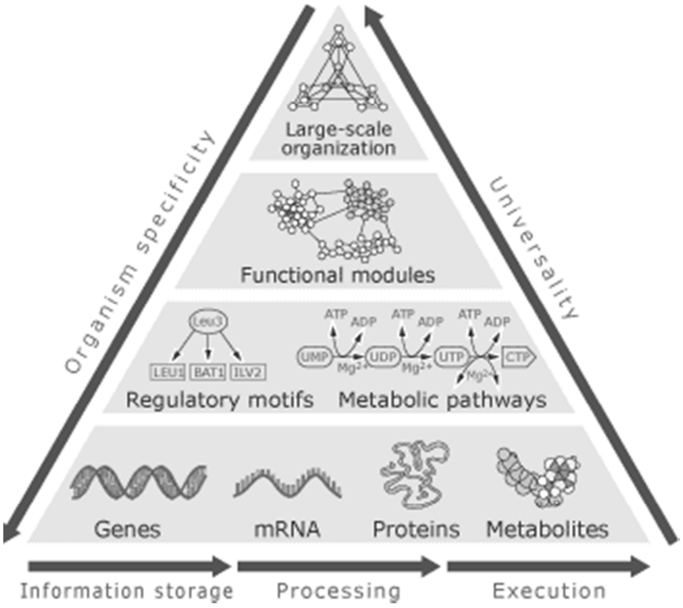

Figure 54. Life's Complexity Pyramid. (Oltvai & Barabási, 2002).[36]

In general, three system theories can be distinguished: the General Systems Theory (GST), Cybernetics, and the Dynamic Systems Theory (DST). Each theory has its own language and application, depending on the perspective of which biological phenomena are viewed. The GST covers mainly the structural organization of living systems. Cybernetics can be used when regulation of living systems is viewed, and the DST deals with the behaviour and interrelatedness of living systems. Together the three systems theories cover the whole scope of biology (Boersma, 1997). Earlier studies by Knippels (2002) and Verhoeff (2003) on systems thinking in biology education focused on the GST.

Nevertheless, in education, systems biology is not a common topic, nor is systems thinking (Grivell, 2009; Rau, Wegener, & Furtado, 2009). In addition, there are different understandings of the definition of systems thinking in education. Defining systems thinking as the competence to understand relationships in dynamic systems is too wide for investigation and education. Therefore, we need a more narrow description. Boersma, Waarlo & Klaassen (2011) understand systems thinking in biology education as the ability to think backward and forward between general systems models and concrete biological objects and processes. Furthermore, to test students' systems thinking ability, they

[34] http://www.sysbio.nl/ (Retrieved November 2011)

[35] http://www.systemsbiology.org/ (Retrieved November 2011)

[36] http://www.msbf.mpg.de/ho_sysb_ov.html, (Retrieved November 2011)

recommend to select objects at different levels of biological organisation with distinct systems boundaries, while the study of Verhoeff (2003) indicates that systems thinking can be introduced by using a carefully outlined LT-strategy consisting of a sequence of modelling activities, considering biological entities as nested open systems. The yo-yo strategy as developed by Knippels (2002) also requires a clear distinction of the boundaries of a system model. The yo-yo strategy copes with the complex nature of inheritance by explicitly distinguishing the levels of biological organization, with the organismic level as starting point. Students have to descend and ascend between different levels of biological organization. In a third study about learning and teaching ecosystem behaviour in secondary education, systems thinking competence was also introduced to understand the dynamics and complexity of ecosystems by computer modelling (Westra, 2008).

However, developing a systems thinking competence is difficult (Boersma, 1997), because students have to switch from concrete to an abstract level (Verhoeff, 2003). Another study reveals the difficulty of learning the micro phenomenon, in biological terms all levels of biological organization below the organismal level. For example, most students use life experiences and external behaviour to interpret the concept of homeostasis of blood sugar (Chang, 2007). Even Westra (2008) concludes that students lack the ability of switching from concrete to abstract level and consequently according to the definition of Boersma, Waarlo & Klaassen (2011), the ability of systems thinking. Students had a difficulty with understanding the complex nature of ecosystems. Furthermore, Westra (2008) reports the difficulties students had with the idea of systems boundaries, especially at the rather abstract level of the population. It is supposable that the same difficulties may evoke in the topic of behaviour.

However, this study of an LT-strategy for behavioural biology differs from the studies of Verhoeff (2003) (cell biology) and Knippels (2002) (genetics). Knippels and Verhoeff studied topics that have impact on several levels of biological organization, while behaviour, according to its definition, is about the levels of whole living organisms and populations (although with the introduction of the stress mechanism the molecular level is also introduced). In addition, both genes and cells are about structures, while behaviour is about a developmental process. Behaviour is an emergent phenomenon, emerging from the continuing interaction of the organism and its environment. Therefore, behaviour should be studied from the Dynamic Systems Theory.

Consequently, modelling behaviour that could predict the behaviour of an organism is not common (or even possible) in current behavioural biology. On the other hand, modelling of behaviour of populations is a subject of research and for example, the results are used to design safe environments for the crowd (Morale, Capasso, & Oelschläger, 2005; Renshaw, 1993).

What are the conditions for systems thinking for behavioural biology? What is an appropriate systems model for behaviour? What is the system and what are its boundaries?

From the definition of behaviour, we define the *boundaries* of the system[37] at the organismal and population level. In addition, the levels of organization between the organismial and the molecular level (e.g. the senses as organs) are not studied in behavioural biology, but are only considered when

[37] The boundaries of the system differ from a behaviour system as is used in behavioural biology. In behavioural biology a behaviour system is build-up of a sequence of behaviour elements. In systems theoretical view behaviour emerges from the system.

necessary. Because of the appearance of populations within an ecosystem, and thus the interaction with the (a)biotic factors and populations, the boundary of the ecosystem must be visible in the system model.

Interaction in a behavioural system always goes through internal and external stimuli. Thereby, internal and external stimuli are close together in studying the causal perspective, but are studied at different levels of biological organization. Internal stimuli address mostly the molecular level, while external stimuli address the organism. Although this distinction avoids confusion, for systems thinking we still can distinguish internal from external stimuli, but both categories of stimuli change constantly and at the same time. In case of considering stimuli as a form of information transfer, information comes from inside and outside the body, is transferred by the body, and emerges into behaviour. The more an organism is (internally) able to process the information, the better it can survive.

In the definition of behaviour (Levitis, Lidicker, & Freund, 2009), developmental changes are excluded. In the light of the dynamic systems theory, development is an emergent appearance. In developmental psychology, the developmental systems theory (or dynamic systems theory) is a perspective on biological development, heredity, and evolution, emphasizing the equal contributions of genes, environment, and epigenetic factors on developmental processes[38]. Therefore, in terms of the systems theory, the exclusion of developmental change could be dismissed in the definition of behaviour, because development is the result of the internally coordinated responses of an organism or population to stimuli. Furthermore, not only the appearance of stimuli, or stressors (those are everywhere, and anytime), but the type, amount and intensity of stressors are important factors.

Modelling behaviour from a systems theoretical view is the next condition for systems thinking. Remarkably, reviewing behavioural biology literature, e.g. ‘The behaviour of animals’ (Bolhuis & Giraldeau, 2005), and ‘Tinbergen's Legacy’ (Bolhuis & Verhulst, 2009), we did not find an indication for a systems theoretical view. It could be argued that this is caused by the strict distinction of the four perspectives of Tinbergen. Only in discussions about the causation of behaviour a model of a behaviour system is included (figure 8). However, taking account of Tinbergen's prediction of a fusion between ethology and psychology, we searched for systems models in psychology, and it appears that systems thinking is developed in theories such as the Living Systems Theory, and Developmental Systems Theory (Parent, 2000). Both are examples of the Dynamic Systems Theory (Thelen & Smith, 1994; Smith & Thelen, 2003). Therefore, because of its interrelatedness and emergent character, behaviour should be the best considered from the view of the DST.

The emergent character of complex living systems means that each higher level contains the next lower level in a nested fashion (Miller, 1978). Therefore, a system model for behaviour should contain such a nested view.

In figure 55 we show a system model for behaviour, which consists of the nested levels of biological organization of the organism (the inner circles), of the population (outer circle), and the level of the ecosystem (outer frame). Behaviour is restricted to the levels of the population and organism (square with the A), the boundaries of the system model. All arrows in the model indicate the interaction between the levels of organization.

[38] https://en.wikipedia.org/wiki/Developmental_systems_theory (Retrieved February 2012)

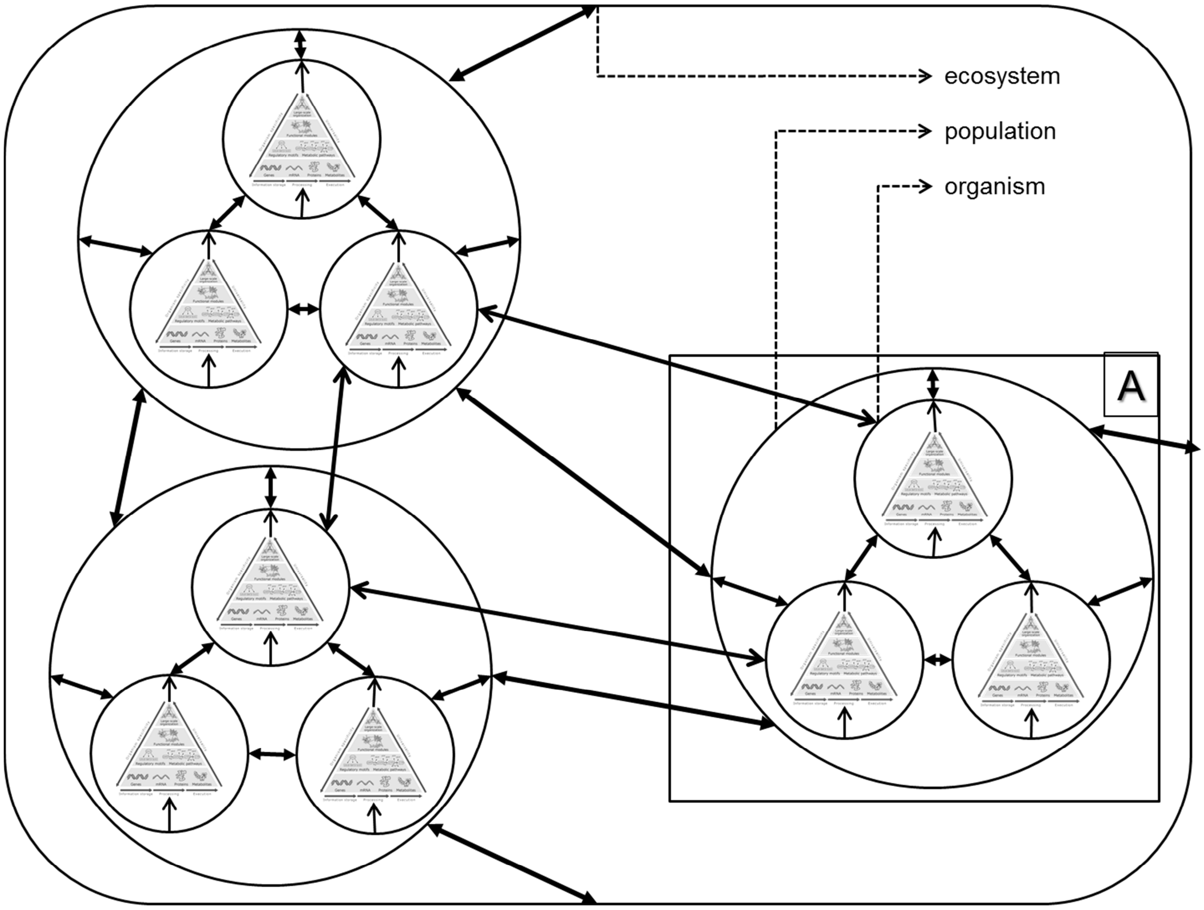

Figure 55. A system model for behaviour. Square A indicates the systems' boundaries. Because of interaction with the levels below and above the organism/population, the level of the ecosystem and the molecular level is also part of the model. The molecular level is shown by the Life's Complexity Pyramid, and can be supplied with the model of internal processing (see figure 16).

In this thesis, we described the model of internal processing (IP) as shown in figure 8, and the model of the stress mechanism (SM, figure 16, and figure 17). The model of internal processing could be considered as complementary to the Life's Complexity Pyramid. With both models, the components interact in space and time. However, the IP-model is placed into an organism and the interaction between its components goes at high speed. The SM-model deals with both the level of the organism and the molecules, while the application at the level of the population would be arguable. The SM-model embraces a large timescale (from milliseconds to days, depending on the organization level). In the former chapters we argued for the use of the SM-model as the binding principle for behaviour. Furthermore, the expanded model of the stress mechanism indicates for space and time (figure 56).
According to the yo-yo strategy, developing systems thinking in behaviour education should start with the organism. The described LT-strategy starts with the organism, and the expanded SM-model is used in the second practice. The third practice in the LT-strategy is at the level of the population, and we found that the change of level of biological organization from the organism to the population seems not to be problematic. However, students did not notice that the practice is about another level of organization, which is one of the characteristics of systems thinking.

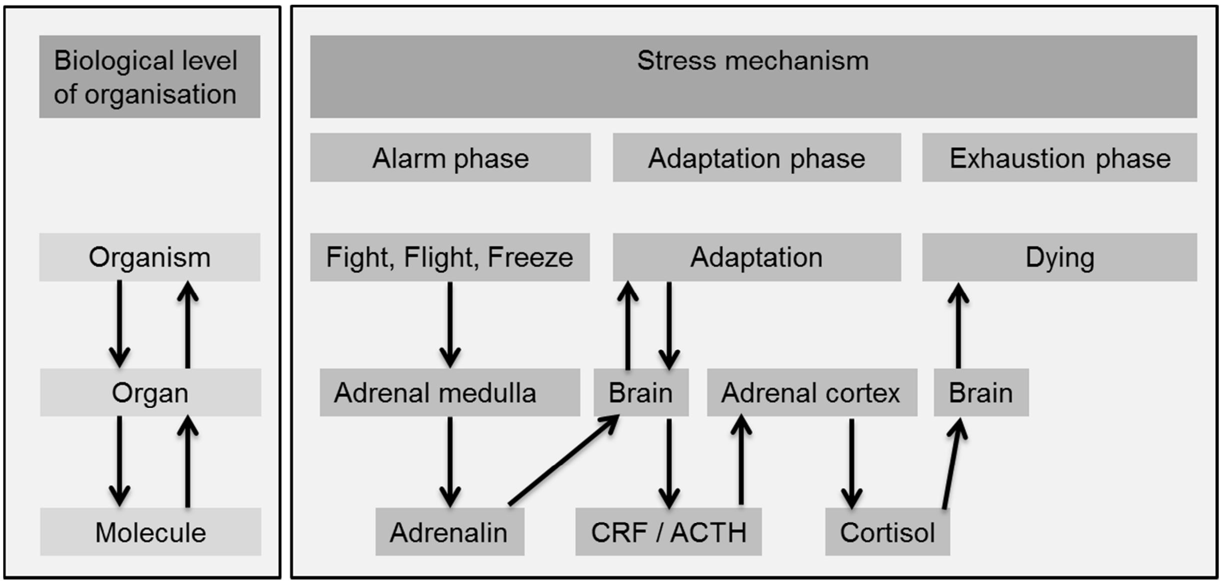

Figure 56. Expanded model of the stress mechanism, whereby time and space are indicated. The arrows, started with Fight, Flight, Freeze, indicates for the route in space and time. The structure of this model is used in the second practice in the LT-strategy.

Actually, the behaviour of a population is an abstraction, emerging from the interaction of a group of organisms with their environment. The question is how students can be invited to think from abstract to concrete level. Therefore, to adequately develop systems thinking competence, we suggest starting an LT-strategy for behavioural biology at the abstract population level, including the understanding of Tinbergen's perspectives. Thereafter, students should change from the population level to the concrete organismal level, to understand the model of the stress mechanism. The final step is thinking upwards again, constructing the system model of behaviour.

For example, the storyline of the first lesson could be as follows. Considering stimuli as causes of behaviour, and that behaviour is directed to survive, in a practice of an emergency with a crowd in a stadium, students have to think abstractly with concrete organisms. People want to survive in case of emergency, and they take flight or fight. In addition, since people dislike uncertainty the importance of information is unquestionable. Furthermore, an evacuation exercise can be seen as a learning process. After a general exploration, the question can be asked what if you were there, or how the behaviour of individuals can be influenced. Applying the problem posing approach to the storyline, figure 57 shows the first cycle of such a focus lesson.

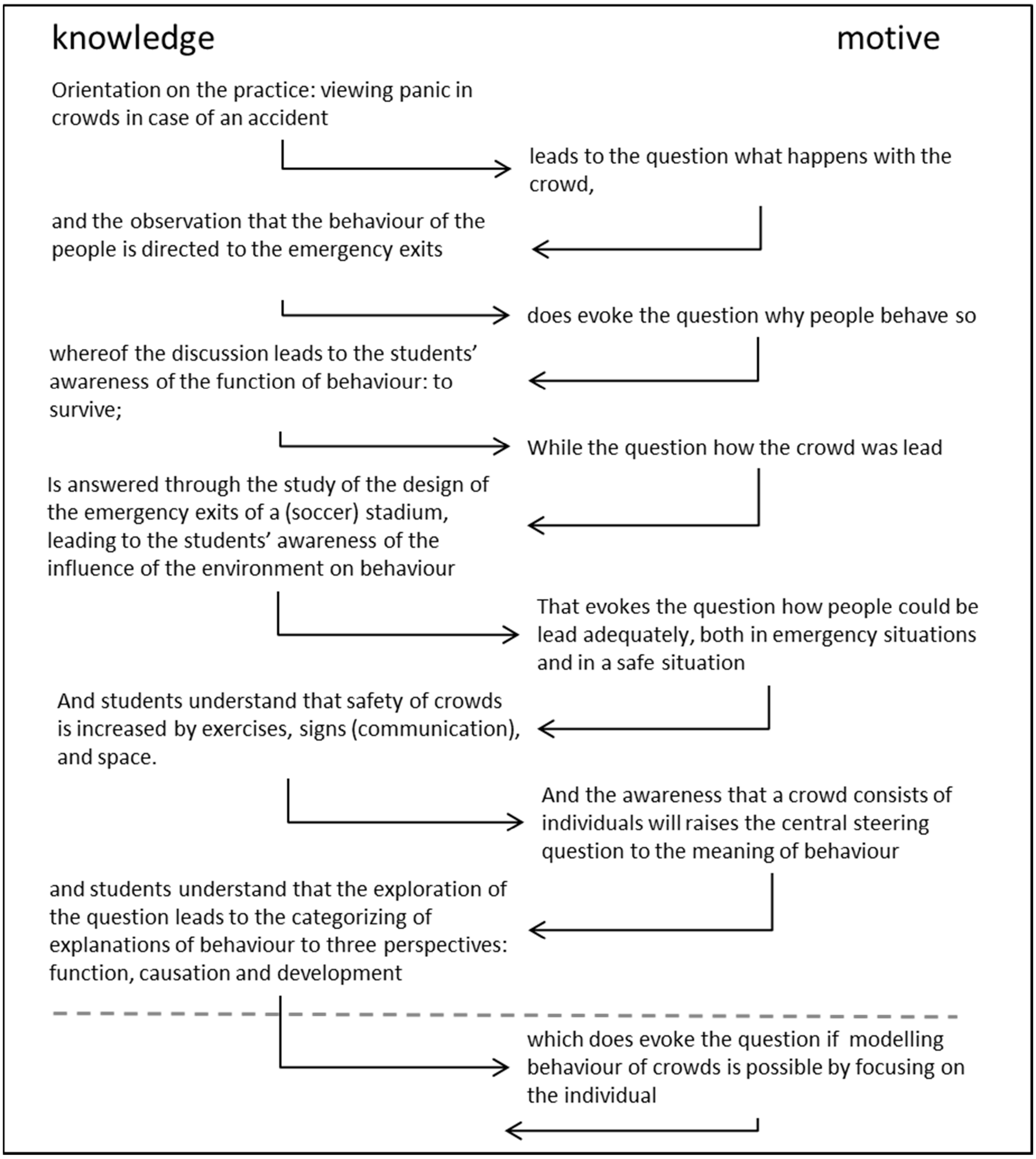

Figure 57. A proposal for the problem posing cycle of the focus lesson, starting at population level.

10.6 Final thoughts: behaviour in the classroom

It seems to be a practical joke to learn and teach about learning processes (or behaviour) without practicing the lessons learnt of behaviour in the classroom. How do you get less stress in lessons? What lesson can we learn from the stress mechanism? Paradoxically, we must both avoid stress situations and introduce stress situations.

Avoiding stress situations touches the educational climate in the classroom. It is the art of teaching to create a pedagogical climate in the lessons, in which trusting and being trusted are the key words. Trust points to the culture, and trusted to the structure in the classroom. Students can acquire self-

confidence, and dare to make mistakes. In a satisfying pedagogical climate students know that they are valued. Ask students why they work for one subject and not for the other, and they usually answer that it depends on the teacher. That is learning by the grace of the relationship!
Performance anxiety can occur at school. Adrenaline is released at the wrong time, but a student cannot fight or flight. Therefore, for a student, 'freeze' is sometimes the only possibility. Causes of performance anxiety can be very diverse: time pressure ("another 5 minutes, boys"), a comment like "do your best", the expectations of parents and the perfectionism of the learner. A teacher who emphasises students' failures encourages the fear of failure. Learning is development, and according to the motivation theory of the psychologist Maslow (1943), safety is a requirement for personal development. A trusted environment is a safe environment, wherein defending (fight, flight, and freeze) is not necessary. Structure, avoiding distraction stimuli, and predictability prevent stress in the classroom. It is the profession of the teacher to create a safe learning environment.

In addition, it is also the professional duty of the teacher to prepare students for a world they cannot imagine (Wiliam, 2011). As we argued, learning processes are induced by the use of problems and steering questions. In terms of the stress mechanism, new, unfamiliar situations induce stress. Therefore, teachers have to introduce 'stressors' in their didactics, and for that they deserve the best tools, and evidence based didactical approaches.

In this thesis we considered 21st century behavioural biology, with systems thinking as a requirement for understanding the complex nature of behaviour. In addition, in preparing students 'for a world they cannot imagine', systems thinking could be considered as an important 21st century skill. Therefore, in education systems, the development of this skill should part of the program.

Finally, being a teacher, researcher, and manager, the research process described in this thesis provided for a personal professionalizing. As a teacher to 'think with the thoughts of students' is an indispensable skill. As a researcher, to think systematically provided for a non-interrupted storyline in this thesis, and the experience of the research process was exciting. As a school leader, adequate management of time and stress was required for finishing this thesis. Being a teacher, researcher, and manager all at once, can be considered as a complex system in itself, mainly managed by curiosity, long-life learning, and systems thinking.

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If a man will begin with certainties, he shall end in doubts,
but if he will be content to begin with doubts,
he shall end in certainties.
Francis Bacon

Summary

1. Introduction

During the last decades biological research showed a spectacular development, bringing many consequences for everyday life and influencing other scientific disciplines. The emergence of 'New Biology' and its social relevance indicates the need for changes in (biology) education, particularly in scientific education, and consequently, also in secondary education. Learning and teaching New Biology requires new educational approaches to acquire knowledge of the (new) biology, competences to understand complex systems, and new strategies to learning and teaching.
However, it is observed that current biology education is not in line with the developments in New Biology. Three main problems are recognized: an overloaded curriculum, limited relevance of the curriculum for students, and a lack of coherence in biological knowledge. In order to reduce these problems in biology education, new examination programmes will be implemented in Dutch upper secondary education, and this implementation is supported by educational research. The so-called concept-context approach is considered as meeting the three main problems in current biology education. However, a strategy for the use of successive contexts in biology education does not exist.

Among all life functions behaviour is considered to be the most all-inclusive and complex expression, which can be characterized by its dynamic and complex nature. Consequently, behavioural biology is considered as a core discipline in New Biology with its cross-links to neurobiology, evolutionary biology, and psychology. Despite its importance, it appears that behavioural biology in Dutch secondary education is largely outdated, and that students are not aware of behaviour. Therefore, the challenge is to develop a learning and teaching strategy (LT-strategy) wherein students acquire an understanding of the dynamic and complex nature of behaviour, both in their own lives and in the lives of other organisms.

2. View on learning and teaching

In chapter 2 we described our view on learning and teaching. Three keywords are important in this view. First, education should focus on the development of the *independence* of students. They must 'learn to think'. Second, students ought to be challenged to be *active* in their own learning processes. Third, thinking also appeals to *imagination*. Narratives trigger the attention and emotions of students, leading to their involvement.
We argued for acquiring functional knowledge that has meaning for students. Meaningful learning 1) requires relevant knowledge and emotional commitment, 2) occurs when students acquire knowledge needed for successful problem solving, and 3) relates new information to a relevant component of an individual's cognitive structure. Knowledge can be characterized by its degree of relevance and usefulness for students. Relevance can be seen as a condition for and act as a process of meaning making.

For a theoretical underpinning of our view on learning and teaching that combines constructivism with a directive role for the teacher, we adopted the cultural historical activity theory (CHAT). The CHAT consists of three main principles: 1) *social interaction* plays a fundamental role in the development of cognition, 2) Cognitive development is enhanced when people work in their *Zone of Proximal Development*, and 3) Cognitive development is led by (mental) *actions*.
Considering motivation and meaning we discussed the Self-Determination Theory (SDT), maintaining that the understanding of human motivation requires a consideration of innate psychological needs for competence, autonomy, and relatedness. Several similarities between the SDT and the CHAT are noticed. Both theories emphasise social interaction and environmental or cultural factors, facilitating cognitive development and (intrinsic) motivation. Social interaction supposes a social practice, wherein an individual requires knowledge to act.
With the starting points of the CHAT and the SDT design criteria for an LT-strategy are developed. These criteria emphasise the use of contexts (authentic social practices), consider learning as the outcome of interaction, prescribe that the design generates the desired motives for students in a logical sequence, and imply that an LT-strategy consists of more than one practice. An educational model is built by the integration of the problem posing approach and the concept-context approach.

3. Developmental research approach

In order to develop an LT-strategy that could be used adequately within educational practice, we require an adequate research method. In essence, an adequate LT-strategy should contribute to the improvement of the educational practice, and the design of an adequate LT-strategy should be developed in interaction with the educational practice in the classroom. Therefore, we used developmental research that is aiming to solve complex problems in educational practice by investigation of both the characteristics of the interventions and the processes evoked by these interventions. Within design experiments domain-specific theories on learning and curricular materials aiming to support that learning are developed. A design is based on hypothesized learning and teaching processes and design experiments are conjecture-driven. During the research process data analyses from several perspectives lead to new sharpened conjectures.
The research plan of this study is structured in an explorative phase and a cyclic research phase. Explorative research is executed in order to determine the domain specific learning and teaching problems. The explorative phase resulted in a domain-specific philosophy of learning and teaching and in building blocks for an LT-strategy. In the research phase, the design criteria were operationalized in a cyclic process of design, field-testing in case studies, reflection, and revision. Two research cycles were planned.

4. Conceptualizing 'behaviour'

Behaviour is inherent to organisms, and is defined as "*the internally coordinated responses (actions or inactions) of whole living organisms (individuals or groups) to internal and/or external stimuli, excluding responses more easily understood as developmental changes.*" Behaviour was studied in ethology. However, nowadays many scientists prefer the term 'behavioural biology', because the study of behaviour also includes new research disciplines such as neurobiology and cognitive psychology. Therefore, we consider the multidisciplinary character of 21st century behavioural biology. The societal relevance of behavioural biology derives from its contribution to animal welfare, the conservation of species and the understanding of human nature.

Behavioural biology is structured according to Tinbergen's four questions:

- What triggers the behaviour?
- How does the behaviour develop?
- What is it for?
- How did the behaviour evolve?

Respectively, these questions are perspectives on the *causes*, the *development*, the *function* and the *evolution* of behaviour. Causation is the immediate effect that external and internal factors have on the occurrence of behaviour. Within behaviour, patterns and systems could be distinguished. Activation of a behaviour system is influenced by internal and external stimuli. The complexity of behaviour increases with the number of behavioural systems involved, and their interactions.

Behaviour patterns and systems develop in a dynamic process. Development is defined as the change in behaviour including the underlying mechanisms in an individual from conception until death. Nothing happens in isolation and each behavioural pattern is affected by many different genes, while each gene influences many different behavioural patterns. Therefore, the stimulus-response is not a single cause reaction, but is elaborated in networks. Behaviour is not only a coordinated process of causation, it is also a developmental process of acquiring behaviour, induced by the mechanism by which individuals interact with and evolve by interaction with the environment. This mechanism is called LEARNING.

The concept FUNCTION has several notions in biology: as an activity, as a biological (causal) role, as the survival value (biological advantage) and as a selected effect. Function as the survival value addresses the function of behaviour. Function as a selected effect addresses the evolution of behaviour.

NATURAL SELECTION is seen as a process that leads to adaptations contributing to an individual's FITNESS. The study of the function of behaviour embraces questions about REPRODUCTION, FEEDING, and DEFENCE.

The outcome of the study of the evolution of behaviour is a reconstruction. Such a reconstruction is to some extent a questionable enterprise, both because of the lack of fossil behaviour and because behaviour is the outcome of internal and external interactions.

Conceptualising behaviour according to 21st century behavioural biology has implications for biology education, and in chapter 4 we discussed the concepts that must be taught in secondary biology education. Because it is impossible to cover all behavioural biology, we made a selection.

Considering the developments in the field of the behavioural sciences we draw three conclusions. First, behavioural biology is a *dynamic* research *field* with many cross-links to other research disciplines that consider behaviour. The second conclusion is that behaviour should be considered as an emergent property of a *dynamic and complex* system. The third conclusion is that concepts of behavioural biology may be *structured* according to the four questions of Tinbergen. An LT-strategy for behavioural biology should be based on design criteria that meet these conclusions, and should pay attention to the social relevance of behavioural biology.

5. Defining educational practice in behavioural biology

We explored the current Dutch educational practice for behavioural biology by investigating the chapter about behaviour in the Dutch biology textbooks and the prior knowledge of students about behaviour. We address our findings to three questions, derived from the formulated design criteria for an adequate LT-strategy.

- To what extent is a broad view of behavioural biology elaborated?
- Is behaviour emphasised in current biology education as dynamic and complex?
- In what manner are the four questions of Tinbergen addressed in Dutch biology textbooks and in students' reasoning?

Although the content of the chapter on behaviour in the textbooks is an adequate interpretation of the prescribed topics about behaviour, it is based on the state of the art in ethology of 30 years ago and it shows a narrow view on behavioural biology. The textbooks do not emphasise the dynamic and complex character of behaviour and lack a reference to the four questions of Tinbergen. On the contrary, behavioural biology concepts are spread over the whole chapter, so there is no coherence between concepts, while evolution of behaviour is generally neglected.

With these textbooks it can be expected that current behavioural biology education does not lead to awareness of behaviour as dynamic and complex, but rather to some general notions of it. The lack of structure by the four questions of Tinbergen and the absence of relations between behavioural biology and other disciplines of biology is not adequate for students' understanding of behaviour.

In our prior research we also concluded that students only have general notions of behaviour and that they are not curious about behaviour. The statement that behaviour is very common for students could answer the question why students did not wonder about behaviour. They were not aware that behaviour is a biological phenomenon that can be investigated.

With these investigated textbooks and the students´ prior knowledge, no 21st century behaviour can be taught. That implies that current education in behavioural biology should be innovated, leading to a greater awareness of behaviour. Therefore, we argued for a selection of relevant behavioural biology concepts, followed by the construction of a coherent web of concepts. In order to select relevant behavioural biology concepts we consulted other educational sources concerning behavioural biology. However, no consistent whole of concepts is found. It seems that behaviour is erroneously not seen as the outcome of a dynamic and complex system. Therefore, it is questionable how a coherent curriculum can be constructed, leading to a better understanding of behaviour.

From the overview of the concepts of 21st century behavioural biology a coherent understanding of the behavioural biology can be safeguarded. The selected concepts are structured according to the perspectives of Tinbergen, distinguished in basic concepts and subordinate concepts. Basic concepts are defined as the minimally needed concepts to understand behavioural biology, and subordinate concepts as (1) non-behavioural biology concepts that express in particular the societal and personal relevance or (2) the behavioural biology concepts that could be omitted to reduce curricular overload.

Many students do not develop coherent biological knowledge, because they do not understand that biological processes include different levels of biological organization. We suppose that conceptual coherence of behavioural biology is evoked when students 1) have the possibility to explore different levels of biological organisation, 2) can relate behavioural biology concepts to their everyday experiences, and 3) when they have the possibility to build up a concept web gradually. Therefore, we describe 1) the use of concept maps as a tool for the step-by-step development of the coherence between behavioural biology concepts, and 2) the introduction of the stress mechanism (General Adaptation Syndrome) as a tool for inducing coherence between the perspectives of Tinbergen and the introduction of different levels of biological organisation.

6. Towards an LT-strategy for behavioural biology

Chapter 6 describes the components of the LT-strategy: the use of contexts (practices), interaction, and the use of motives as a need to act. The global design of the strategy consists of three practices. A central steering question is evoked from the focus lesson, and each practice starts with a steering question. A steering question is derived from the activity of the authentic practice. The first and second practice are aiming to extend students' prior knowledge on behavioural biology with new knowledge, whereby the concepts acquired in the second practice form an extension of the concepts from the first practice. The third practice aims to test students' knowledge on behavioural biology.

An authentic social practice should be educationally appropriate in order to make it suitable for teaching and learning behavioural biology. We formulated five criteria for the selection of social practices. 1) Practices should meet the aims of behavioural biology. 2) Practices should emphasise the levels of biological organization. 3) Practices should elicit motives to increase students' motivation to learn. 4) It should be possible to reduce its complexity. 5) Authentic material of a practice should be available.

For the LT-strategy, we selected the following four authentic social practices:

Practice 1 Caring for your pet (dog) [orientation]

Practice 2a Designing a welfare friendly stable for thousands of pigs [exploration]

Practice 2b Researching the overtraining syndrome [exploration]

Practice 3 Dealing with aggressive people [testing]

In addition, we argued for the use of 'embedded practices' to introduce scientific concepts at the molecular level, and to build a non-interrupted storyline. We define an embedded practice as a (part of a) practice that is necessarily placed into the elaboration of another practice to create a non-interrupted storyline. We claim that an embedded practice 1) should be elaborated preferably within one LTA and has to elicit a motive for a new steering question, 2) is a precondition for acquiring specific (scientific) knowledge for an adequate execution of the LT-activities of the practice, and 3) can provide for coherence in complex behavioural systems by relating the three perspectives.

Each practice, including the focus lesson, is also built up according to the problem posing approach. A reflection phase follows each LT-activity phase, wherein students look back to the steering question of the practice and to the central steering question. After that, a new steering question is evoked, which makes it plausible to change to a new practice.

Participation in a social practice implies learning as the product of interaction between a person and his environment. Interaction in an educational practice is distinguished in three types: learner – teacher, learner – learning tools, and learner –learner.

7. Research instruments

Chapter 7 describes the research instruments. We give an overview of the classroom setting, followed by a justification of the selection of the data collection and analysis. In the two research cycles, eight case studies were included, divided over four secondary schools.

The LT-strategy is elaborated in a scenario that prescribes the storyline of the strategy with all LT-activities of students and teachers and their intentional learning outcomes. This scenario is empirically testable, and data collection was driven by the scenario. Data selection and analysis was focused on answering two questions: 1) Is the scenario executed as intended, and 2) Are the desired learning outcomes achieved? Data were collected from different sources, such as observations by the researcher, audio recordings of classes and groups, and students' concept maps. A model for the analysis of the technical and domain-specific quality of students' concept maps is described.

8. Outline of the intended and executed scenario

Chapter 8 provides for a global overview of the execution of the scenario, focussing on the question if the scenario was executed as intended. The design in first research cycle is considered as a rapid prototype of the LT-strategy for behavioural biology. From a quick scan of the test results in the first research cycle, we concluded that students expressed incorrect connections between the perspectives of Tinbergen, sometimes caused by handling different descriptions of the concepts. Students focused on concrete examples instead of understanding the abstract concepts. The reflection on the first version of the design revealed the following deficiencies:

- A mistake in the design of the focus lesson, including an insufficient explication of the three perspectives on behaviour, resulted in a poorly developed central steering question.
- An unbalance between the needed and available lesson time.
- A lack of profoundness, particularly at vwo level, which resulted in a decrease of the students' motivation and a superficial conceptualisation of behavioural biology.
- Too scare and too reduced reflection phases in the scenario which obstructed recontextualising.

Therefore, four main improvements to the scenario were made in the second research cycle. First, a renewed focus lesson; second, an increased length of the lesson series; third, an increased profoundness, for students on both educational levels (havo and vwo) by introducing the General Adaptation Syndrome; and fourth, the use of more reflection LTAs, including the use of concept maps as a reflection tool.

9. Learning and teaching behavioural biology

To evaluate whether the LT-strategy for behavioural biology is adequate, we investigated students' conceptual development by considering the interaction, reflection, and construction in the executed scenario. For that purpose three educational themes were selected. First, we reviewed the development of a central steering question in the focus lesson. Second, we considered students' conceptual development in the evaluation of the interaction and reflection in the executed scenario. Third, we investigated the knowledge transition by recontextualising, evaluating the construction of knowledge in the students' concept maps and essays.

Development of a central steering question in the focus lesson

The focus lesson is intended to develop the central steering question and Tinbergen's perspectives on behaviour. In the reconstruction of the executed focus lesson, we concluded that observation of the unexpected behaviour of a dog increases the students' awareness of behaviour. Students were stimulated to investigate why that dog behaviour did occur. However, the central steering question, "Why do they do that?" was only implicitly posed by students and explored by the development of Tinbergen's perspectives. Furthermore, the restriction to the behaviour of one animal species (the dog) instead of several species created a non-interrupted storyline. We concluded that students elicited a motive for exploring the first practice. In addition, it is concluded that the teachers' manual provides for adequate preparation of the teacher, which is shown by the different courses of the lesson when teachers either improvised or followed the manual. Overall, we concluded that the focus lesson of the scenario conforms to its purpose, and that the adaption of the scenario was effective.

Students' conceptual development

Three questions were answered.

- To what extent did students understand the three perspectives with their respective behavioural biology concepts?
- To what extent do the reflection phases contribute to the students' conceptual development?
- To what extent do the concept maps as a reflection tool contribute to the students' conceptual development?

Interaction in the LT-strategy was investigated by the analysis of the interaction between teacher¬ and students in the class discussions, and the learning materials. Studying a practice, students made a list of the concepts they considered important for that practice. The lists of the first and second practice include merely concepts of behavioural biology and the stress mechanism, while students wrote the most context-bound concepts in the third practice. These differences reflect the emphasis in the practices very well, underlining what we stated in our view on learning and teaching that knowledge is context-bound. In addition, another difference between the first two practices and the third one is the degree of guidance in the construction of knowledge. In the first and second practice, the list of concepts was made to reflect on the practice, while in the third practice a list of concepts was intended to prepare students for writing an essay. The categorization of the listed concepts according to the three perspectives shows that students often do not explicitly notice them. However, from the self-evaluation and the class discussion it appears that most students are able to recognize the perspectives on behaviour.

It is concluded that generally the scenario is executed as intended, although some organizational difficulties evoked. Teacher behaviour and preparation could be more adequate, and some extensions were made in the LT-strategy, such as a class discussion about WELFARE, NATURAL BEHAVIOUR, and the STRESS MECHANISM. Teachers explained in their feedback that they felt uncertain, because they did not check the students' comprehension of the behavioural biology concepts very well. It could also be concluded that teachers (1) have some difficulties with the understanding of some of the concepts themselves, (2) take too much time for explanation, and (3) regularly forget to evoke motives for

learning. Consequently, the teachers' guidance can be improved by focusing more on the behavioural biology concepts and their coherence.
The analysis of the interaction in the class discussions showed that the LT-strategy structures students' conceptual development, distinguishing the three perspectives on behaviour with their accompanying concepts. Therefore, it is concluded that students' awareness of behaviour is demonstrated.

Reflection activities in the LT-strategy are in particular elaborated at the end of the first and second educational practice. Students made a list of concepts, followed by the construction of concept maps. In addition, a class discussion about a concept map was executed, to create a ‘big picture’ of the behavioural biology concepts. We concluded that adequate reflection time was programmed in the second research cycle. It seemed that students' conceptual development was effectively stimulated by reflection through the construction of concept maps. However, the effective use of concept maps as a reflection tool can be improved by further development of the students (and teachers) skills for concept mapping.
Teachers and students did not always understand the aim of concept mapping.
We investigated the quality of concept maps, both the technical quality, and the domain-specific quality. Only approximately 27% of the students' concept maps meet the condition of having linking phrases as a part of the propositions. Furthermore, it was observed that the concept maps showed a large variety in the number of propositions and structure. Students' concept maps did not include crosslinks, and most students indicated no arrows in their concept maps.
Students used different concepts as starting point of the concept map: BEHAVIOUR, OVERTRAINING, STRESS, and WELFARE. The differences between the technically correct concept maps of the first and second practice were merely context-bound. In general, we concluded that the technical quality of the students’ concept maps is weak, and the process of concept mapping should be improved. It is supposed that the weak quality of the concept maps is caused by a lack of experience in concept mapping by teacher and students. It could be supposed that increasing the technical quality of concept maps also further increases the students' conceptualization.
However, considering the domain-specific quality of the concept maps it appears that students are able to relate the concepts correctly, and that students have a satisfactory understanding of the behavioural biology concepts, in particular STRESS and the STRESS MECHANISM. In addition, students used concepts from outside behavioural biology and the lesson series, or ‘translated’ behavioural biology concepts in their own words. It seems that students reflect on the concepts of the practice in the construction of the concept maps, instead of creating ‘the big picture’ of behavioural biology. The concept maps show a large diversity in the number of propositions and the individual student elaborated an average of 59% of the classifying concepts in a concept map. For most classifying concepts the amount of correct propositions is above 80%, which is high. Therefore, it could be concluded that the evaluation of the domain-specific quality of the concept maps is sufficient to evaluate the students’ understanding of the behavioural biology concepts. The analysis showed that most students are able to relate behavioural biology concepts adequately. In addition, it could be expected that students’ conceptualisation increases further when the construction process of concept maps is improved.

Knowledge transition through recontextualising

Concept maps also support *construction*, the third component of the conceptual development. After two occurrences of using concepts maps as a reflection tool, concept mapping is used in the third practice as a construction tool, preparing students for writing an essay about human aggressive behaviour. Therefore, we investigated the relationship between the domain-specific quality of a concept map and the essay. We concluded that the better the domain-specific quality of the concept map, the better students wrote an essay from a behavioural biology viewpoint. Consequently, we concluded that students can make a high quality concept map when they understand the meaning of and connections between concepts. Students' understanding of behavioural biology concepts increases when they construct a concept map. Therefore, it appears to be important to pay more attention to an adequate construction of concept maps. However, we can also conclude that the LT-strategy for behavioural biology, consisting of several practices, invites students to recontextualise their knowledge.

Adequate reflection and knowledge construction tools, such as concept maps and essay writing, can provide for knowledge transition when the acquired knowledge in one educational practice is adequately (functionally) used in another educational practice. In the test-practice, students wrote an essay from the behavioural biology view as a recommendation to the police for preventing riots. The analysis shows that nearly 80% of the students referred to one or two perspectives (causation, function). The perspective of the development of behaviour was underexposed. The 20% of students who did not refer to any perspective did not adequately follow the instruction of the assignment.

Furthermore, the results showed that students are able to argue from the view of a behavioural biologist. Students used most behavioural biology concepts correctly. In addition, the change of level of biological organization, from the organism to the population, seems not to be problematic.

Recontextualisation is a necessary condition for correct execution of the essay assignment, and it could be concluded that the LT-strategy provides opportunities for recontextualising. Considering the construction of the concept maps and the essays, it appears that the process of the construction of a concept map and the final essay depends on prior knowledge and the constructed understanding. It seems that the more meaningful connections a student shows in the concept map, the better s/he will execute the writing assignment. The LT-strategy for behavioural biology provides opportunities to recontextualise, although some improvements are desirable. Based on the analysis of the essays, we distil possible obstructions for the students' recontextualisation process.

Finally, we have compared the actual learning outcomes with the learning objectives. We conclude that the LT-strategy results in an understanding of the behavioural biology concepts. Students did not distinguish the different perspectives explicitly, but did correctly use the behavioural biology concepts.

10. Discussion and conclusions

In the introduction, we argued that we intended to answer the following research question:

"What are the characteristics of an adequate learning and teaching strategy for behavioural biology in secondary education that increases students' awareness of behaviour as a biological key concept?"

The question whether students' awareness of behaviour is evoked by the LT-strategy can be answered positively. Students adequately conceptualized the behavioural biology concepts, and we concluded that an adequate LT-strategy for behavioural biology can be constructed with the concept-context approach and the problem posing approach. However, some adaptations of the final LT-strategy are proposed.

- The use of concept mapping as a reflection tool could be improved by a systematic construction of concept maps
- Students evaluated some texts in the workbook as too long. Therefore, length, level, and language in the final version of the texts in the workbook have to be adapted.
- The sequence of the steering questions in the (second) practice of the building of a welfare friendly pig stable should be adapted in order to construct a more logical storyline.

The LT-strategy is based on eight design criteria, and in chapter 10 we evaluated whether the design criteria have the desired impact in the LT-strategy.

1. The LT strategy fully meets the design criterion of using a sequence of authentic practices. The practices did have relevance for students, although the unfamiliarity with the approach could evoke feelings of uncertainty. The five criteria for selection of practices clarify how practices can be used in (biology) education.

2. We concluded that the adaptation of the activity of an authentic social practice into learning activities in an educational practice is not problematic. Furthermore, we concluded that the LT-strategy creates a learning environment that promotes interaction, which meets the second design criterion.

3. The elaboration of the problem posing approach in the LT-strategy seemed to be effective. Two obstructions were noticed. First, in the concept maps, students did use different steering questions, and second, the subsequent motives in the practice of designing a stable could have been more logical to form a non-interrupted storyline. Nevertheless, we concluded that the LT-strategy is fully meeting the third design criterion.

4. Considering the use of three practices, the LT-strategy meets the fourth design criterion. However, to evaluate the design criterion, we have to question whether this criterion is effective. To what extent have students learnt to recontextualise behavioural concepts? We defined recontextualising as a result of the concept-context approach, including adequate reflection phases. Nevertheless, it would be recommended to focus further research on the process of recontextualising itself.

5. The LT-strategy meets the design criterion of being based on 21st century behavioural biology. First, by the use of contemporary authentic practices, and second, by the links that are made with physiology, when exploring the concepts STRESS and AGGRESSION with the General Adaptation Syndrome. We observed that the stress mechanism provides the social relevance for students.

6. Are students aware of the dynamic and complex nature of behaviour? The answer to this question is simply that we do not know, because, in retrospect, the LT-strategy only implicitly provides for a systems thinking competence as a tool for understanding the emergent nature of behaviour. In particular systems thinking is required in the exploration of the General Adaptation Syndrome, because in the stress mechanism different levels of biological organisation are involved. We concluded that the LT-strategy for behavioural biology does not fully meet the sixth criterion.

7. Behavioural biology is structured according to the four questions of Tinbergen. With the exception of the question about the evolution of behaviour, we transformed these questions into perspectives on behaviour that students have to use in their exploration of behaviour. It appears that students were able to distinguish the following perspectives on behaviour: function, causation, and development. Therefore, the LT-strategy for behavioural biology meets the learning objective that students should be aware of behaviour as a key concept.
8. We used practices considering the welfare of animals and the nature of human beings. Therefore, we conclude that the LT-strategy for behavioural biology meets the criterion of the social relevance of behavioural biology.

Summarizing, we found that the LT-strategy meets all design criteria, with the exception of the design criterion that an LT-strategy for behavioural biology should emphasise systems thinking competence. Therefore, we conclude that an adequate LT-strategy for behavioural biology has characteristics that meet the design criteria.

Implications
Two didactic themes seem to be important for further exploration because of their implications for biology education: the role of the teacher and systems thinking.
Considering the role of the teacher, we were facing with three problems. First, teachers sometimes improvised in handling the scenario, because of the need for class management. Second, teachers were not as familiar with the behavioural biology concepts as they should have been in order to teach adequately. Third, teachers had difficulties with the understanding of the didactical approaches, particularly the requirement of the LT-strategy for creating a non-interrupted storyline.
Actually, we could consider the role of the teacher from two perspectives: 1) what is the influence of teaching style, and 2) the understanding of how teachers could construct a non-interrupted storyline, using the concept-context approach and the problem posing approach.
We concluded that the LT-strategy for behavioural biology does not focus on the explicit development of systems thinking, because the focus was put on creating a coherent web of concepts. Nevertheless, to understand the dynamic and complex nature of behaviour, the step from the construction of coherence to systems thinking should be taken. Therefore, we explore a didactical approach for teaching and learning of systems thinking in behavioural biology in secondary education.

Finally, we expressed some thoughts about behaviour in the classroom. In education, we are concerned with learning processes and behaviour. It seems to be a practical joke to learn and teach about learning processes (or behaviour) without practicing the lessons learnt about behaviour in the classroom. How do you get less stress in lessons? What lesson can we learn from the stress mechanism? Paradoxically, we must both avoid stress situations and introduce stress situations. Finally, it can be supposed that considering the classroom as a dynamic and complex system may improve students' satisfaction, motivation, and learning results.

Samenvatting

1. Inleiding

De laatste decennia laat het biologisch onderzoek een spectaculaire ontwikkeling zien die veel gevolgen heeft voor het dagelijks leven en die van invloed is op andere wetenschappelijke disciplines. De opkomst en de sociale impact van de 'Nieuwe Biologie' maakt ook veranderingen in het (biologie) onderwijs noodzakelijk, zowel in het wetenschappelijk onderwijs als in het voortgezet onderwijs. Het leren en onderwijzen van de Nieuwe Biologie vereist nieuwe onderwijskundige benaderingen voor het verwerven van kennis van de (Nieuwe) biologie, van competenties om complexe systemen te begrijpen, en van nieuwe strategieën om te leren en onderwijzen. Het blijkt echter dat het huidige biologieonderwijs niet meer aansluit bij de ontwikkelingen in de Nieuwe Biologie. Drie problemen worden onderkend: 1) een overladen curriculum, 2) geringe relevantie van het curriculum voor leerlingen, 3) en een gebrek aan samenhang in de biologische kennis. Om deze problemen in het biologieonderwijs aan te pakken worden nieuwe examenprogramma's in de bovenbouw van het voorgezet onderwijs in Nederland ingevoerd; deze invoering wordt ondersteund door onderwijskundig onderzoek. Hoewel verondersteld wordt dat de zogenaamde concept-context benadering tegemoet komt aan de genoemde drie problemen in het huidige biologieonderwijs, is nog geen onderwijsleerstrategie (OLS) voor het gebruik van meerdere opeenvolgende contexten beschikbaar.

Van alle levensfuncties wordt gedrag als de meest inclusieve en complexe expressie beschouwd: gedrag is dynamisch en complexe van aard. Gedragsbiologie wordt daarom gezien als een kerndiscipline in de Nieuwe Biologie met dwarsverbanden naar de neurobiologie, evolutionaire biologie, en psychologie. Niettemin, ondanks deze importantie blijkt dat gedragsbiologie in het Nederlandse biologieonderwijs niet actueel meer is en dat leerlingen niet beseffen dat gedrag een levensfunctie is. De uitdaging is daarom om een OLS voor gedragsbiologie te ontwerpen waarin leerlingen begrip verwerven van de complexe en dynamische aard van gedrag, zowel in hun eigen leven, als in het leven van andere organismen.

2. Visie op leren en lesgeven

Hoofdstuk 2 beschrijft onze visie op leren en lesgeven. Drie kernwoorden zijn daarin belangrijk. 1) onderwijs moet gericht zijn op de ontwikkeling van de *zelfstandigheid* van leerlingen. Zij moeten 'leren denken.' 2) leerlingen moeten uitgedaagd worden om *actief* te zijn in hun eigen leerproces. 3) Denken doet een beroep op *verbeelding*. Verhalen vangen de aandacht en prikkelen de emoties van leerlingen en leiden tot betrokkenheid. Een verhaal kan ook begrepen worden als een persoonlijke voorstelling van een authentieke sociale praktijk.

Kennis wordt gewaardeerd op grond van de mate van relevantie en de mate van bruikbaarheid voor leerlingen. We beargumenteren dat het verwerven van functionele kennis voor leerlingen van belang is. Betekenisvol leren 1) vraagt relevante kennis en emotionele betrokkenheid, 2) treedt op wanneer leerlingen cognitieve processen en kennis verwerven die nodig zijn voor het succesvol oplossen van problemen, en 3) relateert nieuwe relevante informatie aan iemands cognitieve structuur. Persoonlijke relevantie kan worden gezien als een *voorwaarde* voor en het handelen als een *proces* van betekenisverlening.

Voor een theoretische onderbouwing van onze visie op leren en onderwijs dat constructivisme met een sturende rol voor de leraar combineert, hanteren we de cultuur-historische activiteit theorie (CHAT). In de CHAT zijn drie principes leidend.1) Sociale interactie speelt een fundamentele rol in de cognitieve ontwikkeling. 2) Cognitieve ontwikkeling wordt bevorderd wanneer mensen in hun zone van naaste ontwikkeling werken. 3) Cognitieve ontwikkeling wordt gestuurd door (mentale) acties.
In de benadering van motivatie en betekenis sluiten we aan bij de Self-Determination Theory (SDT). De SDT gaat ervan uit dat menselijke motivatie ontstaat als tegemoet gekomen wordt aan aangeboren psychologische behoeften aan competentie, autonomie en relatie. Zowel de SDT als de CHAT benadrukken dat sociale interactie en omgevings- of culturele factoren de cognitieve ontwikkeling en (intrinsieke) motivatie stimuleren. Sociale interactie veronderstelt een sociale praktijk, waarin een individu kennis nodig heeft om te handelen.
Vanuit de uitgangspunten van de CHAT en de SDT worden ontwerpcriteria voor een OLS ontwikkeld. Deze criteria benadrukken het gebruik van meerdere contexten (authentiek sociale praktijken), beschouwen leren als het resultaat van de interactie en schrijven voor dat het ontwerp de gewenste motieven voor leerlingen in een logische volgorde genereert. De probleemstellende en de concept-context benadering werden in één model geïntegreerd.

3. Ontwikkelingsonderzoek

In essentie moet een OLS bijdragen aan de verbetering van de onderwijspraktijk. Een strategie moet daarom ook ontwikkeld worden in wisselwerking met die onderwijskundige praktijk. Daarom is gebruik gemaakt van ontwikkelingsonderzoek dat bedoeld is om complexe problemen in de onderwijspraktijk op te lossen door zowel de karakteristieken van de onderwijskundige interventies als ook het onderwijsleerproces dat ontstaat door deze interventies te onderzoeken. Binnen ontwerp-experimenten worden zowel een domein-specifieke leertheorie als leermaterialen die dat leren ondersteunen ontwikkeld. Een ontwerp is uitgewerkt tot een hypothetisch onderwijsleerproces, waarna de hypothesen waarop dat is gebaseerd en in de klassenpraktijk worden getoetst. Gedurende het onderzoeksproces leidt data analyse tot nieuwe, aangescherpte hypotheses.
In het onderzoeksplan voor deze studie werden een exploratieve fase en een cyclische onderzoeksfase onderscheiden. Verkennend onderzoek resulteerde in een domein-specifieke visie op leren en les geven en bouwstenen voor een OLS. In de cyclische onderzoeksfase werden de ontwerpcriteria geoperationaliseerd in een cyclisch proces van ontwerp, praktijkonderzoek in case studies, reflectie en revisie. Er werden twee onderzoekcycli gepland.

4. Het conceptualiseren van ‘gedrag’

Gedrag is inherent aan een organisme en gedefinieerd als “de intern gecoördineerde respons (al dan niet handelend) van levende organismen (individuen of groepen) op interne en/of externe prikkels, uitgezonderd de reacties die als ontwikkelingsprocessen zijn te begrijpen.” Gedrag werd bestudeerd in de ethologie, maar hedendaagse wetenschappers geven de voorkeur aan de term gedragsbiologie, omdat de studie van gedrag ook nieuwe onderzoeksgebieden betreft, zoals de neurobiologie en de cognitieve psychologie. We gaan daarom uit van het multidisciplinaire karakter van de 21e eeuwse gedragsbiologie. De sociale relevantie van de gedragsbiologie blijkt uit haar bijdrage aan dierenwelzijn, het behoud van soorten en het begrijpen van de menselijke natuur. Gedragsbiologie wordt gestructureerd volgens de vier vragen van Tinbergen:

- Wat zijn de oorzaken van gedrag?
- Hoe ontwikkelt gedrag?
- Waar dient gedrag voor?
- Hoe evolueerde gedrag?

Deze vragen zijn perspectieven op de oorzaken, de ontwikkeling, de functie en de evolutie van gedrag. CAUSATIE is het directe effect van externe en interne prikkels op het voorkomen van gedrag. Een onderscheid kan worden gemaakt in gedragspatronen en gedragssystemen. Activering van een gedragssysteem wordt beïnvloed door interne en externe prikkels. De complexiteit van gedrag neemt toe naarmate het aantal betrokken systemen toeneemt, inclusief de interactie daartussen.

Gedragspatronen en –systemen ontwikkelen in een dynamisch proces. ONTWIKKELING wordt daarom gedefinieerd als de verandering in gedrag, inclusief het onderliggende mechanismen in een individu vanaf de conceptie tot de dood. Niets gebeurt geïsoleerd en elk gedragspatroon wordt beïnvloed door veel verschillende genen, terwijl een gen veel verschillende gedragspatronen kan beïnvloeden. Daarom gaat het in stimulus-response relaties niet enkelvoudige oorzaken, maar om causale netwerken. Gedrag is niet alleen een gecoördineerd proces van oorzaken, maar ook een ontwikkelingsproces waarin gedrag wordt verworven, geïnduceerd door het mechanisme waarmee individuen interageren met en dat betrokken is bij de interactie met de omgeving. Dit mechanisme wordt LEREN genoemd.

Het begrip FUNCTIE kent in de biologie verschillende betekenissen: als een activiteit, in een biologische causale rol, als de overlevingswaarde (biologisch voordeel), en als een geselecteerd effect. Functie als de overlevingswaarde betreft de functie van gedrag. Functie als geselecteerd effect betreft de evolutie van gedrag. Natuurlijke selectie is dan een proces dat leidt tot aanpassingen die bijdragen aan de fitness van een individu. De studie van de functie van gedrag omvat vragen naar de voortplanting, verdediging, en voeding. De uitkomst van de studie van de evolutie van gedrag is een reconstructie. Een dergelijke reconstructie is een twijfelachtige onderneming, omdat fossiel gedrag niet bestaat, en omdat gedrag het resultaat is van interne en externe interacties.

Het conceptualiseren van gedrag op basis van de 21e eeuwse gedragsbiologie heeft implicaties voor het biologieonderwijs en in hoofdstuk 4 worden de begrippen bediscussieerd die onderwezen zouden moeten worden in het voortgezet onderwijs. Omdat het onmogelijk is om in het voortgezet onderwijs alle gedragsbiologie te onderwijzen is een selectie van begrippen gemaakt. Rekening houdend met de ontwikkeling van het vakgebied van de gedragsbiologie worden drie conclusies getrokken. Allereerst dat gedragsbiologie een dynamisch onderzoeksgebied is met veel dwarsverbanden naar andere disciplines die gedrag onderzoeken. Vervolgens, dat gedrag moet worden beschouwd als een emergente eigenschap van een dynamisch en complex systeem. De derde conclusie is dat gedragsbiologische begrippen worden gestructureerd op grond van de vier vragen van Tinbergen. Een OLS voor gedragsbiologie zou daarom gebaseerd moeten zijn op ontwerpcriteria die tegemoet komen aan deze conclusies, en waarbij bovendien aandacht besteed wordt aan de sociale relevantie van de gedragsbiologie.

5. Gedragsbiologie in de huidige onderwijspraktijk

We zijn de huidige Nederlandse onderwijspraktijk voor gedragsbiologie nagegaan door zowel het hoofdstuk gedrag in de Nederlandse biologieschoolboeken als de voorkennis van leerlingen ten aanzien van gedrag te onderzoeken. De bevindingen zijn beoordeeld aan de hand van drie vragen die voortvloeiden uit de geformuleerde ontwerpcriteria voor een adequate OLS.

- In welke mate is een brede visie op gedragsbiologie uitgewerkt?
- Wordt het dynamische en complexe karakter van gedrag in het biologieonderwijs benadrukt?
- Op welke manier zijn de vier vragen van Tinbergen terug te vinden in de Nederlandse biologieschoolboeken en in de redeneringen van leerlingen?

Hoewel de inhoud van het hoofdstuk Gedrag in de schoolboeken een adequate interpretatie is van de voorgeschreven eindtermen over gedrag, is het gebaseerd op de ethologie van 30 jaar geleden en laat het een smalle visie op de gedragsbiologie zien. De leerboeken benadrukken niet het dynamische en complexe karakter van gedrag en missen elke referentie naar de vier vragen van Tinbergen. Integendeel, gedragsbiologische begrippen zijn zo verspreid over het hele hoofdstuk dat samenhang tussen de begrippen ontbreekt. Evolutie van gedrag wordt over het algemeen genegeerd.

Verwacht kan worden dat het huidige onderwijs in de gedragsbiologie met deze leerboeken bij leerlingen niet leidt tot het besef dat gedrag dynamisch en complex is, maar slechts tot algemene noties van gedrag. Het gebrek aan structuur door de vier vragen van Tinbergen en het gemis aan verbanden met andere biologie disciplines zullen leerlingen geen begrip geven van gedrag. In het vooronderzoek concludeerden we dan ook dat leerlingen slechts algemene noties van gedrag hebben en dat zij niet nieuwsgierig zijn naar gedrag. De veronderstelling dat gedrag voor leerlingen zo gewoon is beantwoordt de vraag waarom leerlingen zich niet over gedrag verwonderen. Zij waren zich niet bewust dat gedrag een biologisch fenomeen is dat kan worden onderzocht.

Met deze onderzochte schoolboeken en de voorkennis van leerlingen kan gedrag niet op een hedendaagse wijze worden onderwezen. Dat impliceert ook dat het huidige biologieonderwijs voor gedrag aan vernieuwing toe is. Daarvoor is in deze studie een selectie van relevante concepten van de gedragsbiologie bepleit, en wordt een opbouw van een samenhangend netwerk van begrippen beargumenteerd. Met het oog op deze selectie van relevante concepten van de gedragsbiologie zijn andere bronnen over gedragsbiologie in het onderwijs geraadpleegd. Daarin valt echter geen consistent geheel van concepten op te merken, en evenmin een doorlopende leerlijn over verschillende opeenvolgende leerjaren. Het lijkt erop dat het gedrag niet wordt gezien als het resultaat van een dynamisch en complex systeem. Daarom is de vraag hoe een coherent curriculum kan worden geconstrueerd, leidend tot een beter begrip van gedrag.

Uit het overzicht van de concepten van de gedragsbiologie van de 21e eeuw kan een samenhangend inzicht van de gedragsbiologie worden verkregen. De geselecteerde begrippen worden gestructureerd op basis van de perspectieven van Tinbergen en onderscheiden in basisbegrippen en ondergeschikte begrippen. Basisbegrippen worden gedefinieerd als de minimaal benodigde begrippen om gedragsbiologie te begrijpen. Ondergeschikte begrippen worden gedefinieerd als (1) niet-gedragsbiologie concepten die in het bijzonder de maatschappelijke en persoonlijke relevantie uitdrukken of (2) de gedragsbiologie begrippen die kunnen worden weggelaten om de overladenheid te voorkomen.

We veronderstellen dat conceptuele coherentie van de gedragsbiologie opgeroepen wordt als leerlingen 1) de mogelijkheid hebben om verschillende niveaus van biologische organisatie te verkennen, 2) gedragsbiologische begrippen kunnen relateren aan hun dagelijkse ervaringen, en 3) als zij de mogelijkheid hebben om een netwerk van begrippen geleidelijk aan op te bouwen. Daarom beschrijven we 1) het gebruik van een concept map als een instrument voor de stapsgewijze ontwikkeling van de samenhang tussen concepten van de gedragsbiologie, en 2) de invoering van het stress mechanisme (General Adaptation Syndrome) als een instrument om samenhang tussen de perspectieven van Tinbergen aan te brengen en verschillende biologische organisatieniveaus te introduceren.

6. Naar een onderwijsleerstrategie voor gedragsbiologie

Hoofdstuk 6 beschrijft de onderdelen voor de OLS: het gebruik van contexten (praktijken), interactie, en het gebruik van motieven als een noodzaak om te handelen. Het globale ontwerp van de strategie bestaat uit drie praktijken. Een centrale stuurvraag wordt opgeroepen in de focusles en elke praktijk begint met een eigen stuurvraag die is afgeleid van de activiteit van de gebruikte authentieke praktijk. De eerste en tweede praktijk zijn gericht op het uitbreiden van de voorkennis van leerlingen van gedragsbiologie met nieuwe kennis, waarbij de begrippen die in de tweede praktijk worden geleerd een uitbreiding vormen van de begrippen uit de eerste praktijk. De derde praktijk beoogt de kennis van leerlingen over gedragsbiologie te toetsen.

Een authentieke sociale praktijk moet worden aangepast om deze geschikt te maken voor het onderwijzen en leren van gedragsbiologie. Vijf criteria voor de selectie van sociale praktijken zijn geformuleerd. 1) Praktijken moeten voldoen aan de doelstellingen van de gedragsbiologie. 2) Praktijken moeten de niveaus van biologische organisatie benadrukken. 3) Praktijken moeten motieven ontlokken om leerlingen te motiveren om te leren. 4) Het moet mogelijk zijn om complexiteit van de praktijk te reduceren. 5) Authentiek materiaal van een praktijk moet beschikbaar zijn.

Voor de OLS werden de volgende vier sociale praktijken geselecteerd:

Praktijk 1	Zorgen voor je huisdier (hond) [oriëntatie]
Praktijk 2a	Ontwerpen van een welzijnsvriendelijke stal voor varkens [exploratie]
Praktijk 2b	Onderzoeken van het overtrainingssyndroom [exploratie]
Praktijk 3	Omgaan met agressieve mensen [toetsing]

Daarnaast werd het gebruik van ‘ingesloten praktijken’ beargumenteerd om wetenschappelijke concepten te introduceren op moleculair niveau en om een ononderbroken verhaallijn op te bouwen.

Een ingesloten praktijk wordt gedefinieerd als een (deel van een) praktijk die noodzakelijk is ingepast in een andere praktijk om een ononderbroken verhaallijn maken. Een ingesloten praktijk 1) kan bij voorkeur worden uitgewerkt binnen een OL-activiteit en moet een motief uitlokken voor een nieuwe stuurvraag, 2) kan een voorwaarde zijn voor het verwerven van specifieke (wetenschappelijke) kennis voor een adequate uitvoering van de OL-activiteiten van de praktijk, en 3) kan zorgen voor samenhang tussen complexe gedragssystemen door de drie perspectieven aan elkaar te verbinden.

Elke praktijk, inclusief de focusles, is opgebouwd volgens de probleemstellende benadering. Een reflectiefase volgt op de fase van OL-activiteiten. Leerlingen reflecteren daarin op de stuurvraag van de praktijk en op de centrale stuurvraag. Daarna moet een nieuwe stuurvraag worden opgeroepen waardoor het voor leerlingen aannemelijk wordt om te schakelen naar een nieuwe praktijk. Deelname aan een sociale praktijk houdt in dat het leren gezien wordt als het product van de interactie met de omgeving. In de onderwijspraktijk worden drie soorten interactie onderscheiden: leerling - leraar, leerling - leermiddelen en leerling - leerling.

7. Onderzoeksinstrumenten

Hoofdstuk 7 beschrijft de onderzoeksinstrumenten. Eerst wordt een overzicht gegeven van de scholen die aan de casestudies hebben meegedaan, daarna wordt een verantwoording gegeven van de dataverzameling en -analyse. In twee onderzoek cycli werden acht casestudies opgenomen, verdeeld over vier middelbare scholen (bovenbouw havo en vwo).

De OLS is uitgewerkt in een scenario dat de verhaallijn van de strategie met alle OL-activiteiten van voor leerlingen en docenten voorschrijft en de vooronderstelde leeropbrengst aangeeft. Het scenario is empirisch toetsbaar en geeft sturing aan de dataverzameling. Dataselectie en -analyse werden gebaseerd op de volgende twee vragen: 1) Is het scenario uitgevoerd zoals bedoeld?, en 2) Zijn de gewenste resultaten bereikt? Data werden verzameld uit verschillende bronnen, zoals observaties door de onderzoeker, audio-opnamen van de klassen en groepen, en concept maps van leerlingen. Een analysemodel voor de technische en domein-specifieke kwaliteit van de concept maps van leerlingen wordt beschreven.

8. Overzicht van het voorgenomen en uitgevoerde scenario

Hoofdstuk 8 geeft een globaal overzicht van de uitvoering van het scenario, gefocust op de vraag of het scenario werd uitgevoerd zoals de bedoeling was. Uit een globale scan van de resultaten van de toets in de eerste onderzoekcyclus werd geconcludeerd dat leerlingen onjuiste verbindingen tussen de perspectieven van Tinbergen leggen, soms veroorzaakt door het hanteren van verschillende definities van begrippen. Leerlingen bleven steken in concrete voorbeelden in plaats van de abstracte concepten te begrijpen. De volgende gebreken kwamen aan het licht bij de reflectie op de eerste versie van het ontwerp:

- Een fout in het ontwerp van de focusles, inclusief onvoldoende uitleg van de drie perspectieven op gedrag, resulteerde in een slecht ontwikkelde centrale stuurvraag.
- Een disbalans tussen de benodigde en beschikbare lestijd.
- Een gebrek aan diepgang, in het bijzonder op vwo-niveau, dat in een gebrek aan motivatie van leerlingen en een oppervlakkige conceptualisering van de gedragsbiologie resulteerde.
- Te weinig en te korte reflectiefasen in het scenario waardoor recontextualisatie werd beperkt.

Daarom werd in de tweede onderzoekcyclus het scenario verbeterd door de focusles te vernieuwen, de lessenserie uit te breiden tot 12 lessen, een grotere diepgang mogelijk te maken door op beide niveaus (havo en vwo) het stress mechanisme te introduceren, en de inpassing van meer reflectie activiteiten inclusief het gebruik van concept maps als reflectie-instrument.

9. Leren en onderwijzen van gedragsbiologie

Om te beoordelen of de OLS voor gedragsbiologie adequaat is, is de begripsontwikkeling van leerlingen onderzocht door de analyse van de *interactie*, *reflectie* en *constructie* in het uitgevoerde scenario. Voor dat doel werden drie thema's geselecteerd. Eerst werd de herziening van een centrale stuurvraag in de focusles geëvalueerd. Ten tweede, werd de conceptuele ontwikkeling van leerlingen onderzocht door de evaluatie van de interactie en reflectie-activiteiten in het uitgevoerde scenario. Ten derde werd onderzocht hoe de kennis transitie door recontextualisatie verliep door de evaluatie van de kennisconstructie in de concept maps en essays van leerlingen.

Focusles

De focusles is bedoeld om de centrale stuurvraag en Tinbergens' perspectieven op gedrag te ontwikkelen. In de reconstructie van de uitgevoerde focusles werd geconcludeerd dat observatie van het onverwachte gedrag van een hond de leerlingen bewust maakt van gedrag als een biologisch onderwerp. Leerlingen werden gestimuleerd om te onderzoeken waarom dat gedrag van hond zich voordeed. De centrale stuurvraag, "Waarom doet hij dat?" werd echter door leerlingen slechts impliciet gesteld en werd vooral onderzocht door de ontwikkeling van Tinbergens' perspectieven op gedrag. Verder zorgde de beperking tot het gedrag van één diersoort (de hond) in plaats van meerdere diersoorten voor een ononderbroken verhaallijn. Geconcludeerd werd dat in de focusles bij leerlingen een motief werd opgeroepen voor het verkennen van de eerste praktijk. Bovendien werd geconcludeerd dat de handleiding in een adequate voorbereiding van de leraar voorziet, wat bleek uit het verschil in het verloop van de lessen wanneer leraren improviseerden of de handleiding volgden. We concludeerden dat de focusles van het scenario doelmatig was en dat de aanpassing van het scenario effectief was.

Begripsontwikkeling van leerlingen

De volgende drie vragen werden beantwoord.

1. In welke mate begrijpen leerlingen de drie perspectieven met hun bijbehorende gedragsbiologische begrippen?
2. In welke mate dragen de reflectiefasen bij aan de begripsontwikkeling van leerlingen?
3. In welke mate dragen de concept maps als een reflectie-instrument bij aan de begripsontwikkeling van leerlingen?

Interactie in de OLS werd onderzocht door de interactie tussen docenten en leerlingen in de onderwijsleergesprekken te analyseren en de gegevens over hun interactie met lesmaterialen. Leerlingen maakten een lijst van de begrippen die zij als belangrijk beschouwden voor de praktijk waaraan zij deelnamen. De lijsten van de eerste en tweede praktijk omvatten vooral concepten van de gedragsbiologie en het stress mechanisme, terwijl in de derde praktijk de meeste context-gebonden

begrippen werden opgeschreven. Deze verschillen ondersteunen de visie dat kennis context-gebonden is. Een ander verschil is de mate van begeleiding in de kennis constructie tussen de eerste twee praktijken en de derde. In de eerste en tweede praktijk werd de lijst van begrippen samengesteld om te reflecteren op de praktijk, terwijl in de derde praktijk een lijst nodig was als voorbereiding op het schrijven van een essay.
De indeling van de door leerlingen genoemde begrippen in de drie perspectieven laat zien dat leerlingen vaak impliciet deze perspectieven wel zien, maar niet noemen. Uit de zelfevaluatie en de onderwijsleergesprekken bleek echter dat de meeste leerlingen in staat zijn om de perspectieven op gedrag te herkennen.

Geconcludeerd wordt dat het scenario over het algemeen werd uitgevoerd zoals werd bedoeld, hoewel zich enkele organisatorische moeilijkheden voordeden. Door docenten werd de OLS op enkele plaatsen uitgebreid, onder meer door het invoegen van een onderwijsleergesprek over WELZIJN, NATUURLIJK GEDRAG, en het STRESS MECHANISME. We concludeerden dat leraren (1) soms zelf problemen hebben met het begrijpen van sommige van de begrippen, (2) te veel tijd nemen voor uitleg, en (3) regelmatig vergeten om motieven voor leren op te roepen. Daaruit volgt dat de docentbegeleiding kan worden verbeterd door meer te focussen op de begrippen van de gedragsbiologie en hun samenhang.
Uit de analyse van de interactie in de onderwijsleergesprekken bleek dat de OLS de begripsontwikkeling van leerlingen structureert door het onderscheiden van de drie perspectieven op gedrag met hun bijbehorende concepten. We concludeerden bovendien dat de OLS de leerlingen aantoonbaar bewust maakt van gedrag.

Reflectie-activiteiten in de OLS zijn vooral aan het einde van de eerste en tweede gedidactiseerde praktijk uitgevoerd. Leerlingen maakten een lijst van begrippen, gevolgd door de bouw van een concept map. Bovendien werd een onderwijsleergesprek over een concept map gehouden om een ‘big picture’ van de gedragsbiologische begrippen te maken. Geconcludeerd werd dat in de tweede onderzoekscyclus voldoende lestijd was geprogrammeerd. Het lijkt dat de begripsontwikkeling van leerlingen effectief gestimuleerd werd door reflectie met behulp van concept maps. Echter, het gebruik van concept maps als een reflectie instrument kan effectiever door de verdere ontwikkeling van vaardigheden van de leerlingen (en docenten) voor de constructie van concept maps. Docenten en leerlingen begrepen niet altijd de functie van concept maps.

We onderzochten de kwaliteit van de *concept maps*, zowel de technische kwaliteit, als de domein-specifieke kwaliteit. Slechts 27% van de concept maps voldeed aan de voorwaarde dat proposities bestaan uit concepten en verbindingszinnen. Bovendien vertoonden de concept maps een grote verscheidenheid in het aantal proposities en structuur. Concept maps bevatten geen crosslinks en de meeste leerlingen gaven in hun concept maps geen pijlen weer. Leerlingen gebruikten verschillende begrippen als uitgangspunt van hun concept map: GEDRAG, OVERTRAINING, STRESS en WELZIJN. De verschillen tussen technisch correcte concept maps van de eerste en tweede praktijk zijn vooral contextgebonden. In het algemeen wordt geconcludeerd dat de technische kwaliteit van de concept maps van leerlingen zwak is en dat concept mapping kan worden verbeterd. Verondersteld wordt dat de zwakke kwaliteit van de concept maps wordt veroorzaakt door een gebrek aan ervaring van docent en leerlingen daarmee. Het is ook aannemelijk dat verbetering van de technische kwaliteit van concept mappen de begripsvorming bij leerlingen vergroot.

Niettemin, uit de analyse van de domein-specifieke kwaliteit van de concept maps blijkt dat leerlingen in staat zijn om begrippen correct met elkaar te verbinden en dat leerlingen voldoende begrip hebben van de gedragsbiologische begrippen, in het bijzonder van de begrippen stress en het stress mechanisme. Leerlingen gebruikten begrippen van buiten de gedragsbiologie en de lessenserie of 'vertaalden' gedragsbiologische begrippen in hun eigen woorden. Het lijkt erop dat leerlingen reflecteren op de begrippen uit de praktijk als ze daarover een concept map maken, in plaats van een 'big picture' te maken van de gedragsbiologie. De concept maps vertonen grote verschillen in het aantal proposities en gemiddeld gebruikt een leerling 59% van de geselecteerde begrippen in een concept map. Voor de meeste van deze begrippen ligt de hoeveelheid correcte proposities boven de 80%, wat hoog te noemen is. Daarom wordt geconcludeerd dat met de evaluatie van de domein-specifieke kwaliteit van concept maps kan worden volstaan om het begrip van de gedragsbiologie bij leerlingen te evalueren. Daarnaast wordt verwacht dat de begripsvorming bij leerlingen verder toeneemt als het constructieproces van concept maps verder verbeterd wordt.

Kennis transitie door recontextualiseren

Het maken van concept maps stimuleert ook de kennis*constructie*, het derde onderdeel van de conceptuele ontwikkeling. Na twee keer concepten maps te hebben gebruikt als reflectie-instrument werd in de derde praktijk het concept mappen gebruikt als een constructie-instrument: het voorbereiden van leerlingen voor het schrijven van een essay over menselijke agressief gedrag. Daarom werd de relatie tussen de domein-specifieke kwaliteit van een concept map en het essay onderzocht. Geconcludeerd werd dat hoe beter de domein-specifieke kwaliteit van de concept map, hoe beter leerlingen een essay schreven vanuit het gezichtspunt van de gedragsbiologie. Daarom werd geconcludeerd dat leerlingen een concept map van hoge kwaliteit maken wanneer ze de betekenis van en de verbindingen tussen concepten begrijpen. Het begrip van gedragsbiologische concepten neemt toe wanneer leerlingen een technisch correcte concept map construeren. Daarom lijkt het belangrijk meer aandacht te besteden aan een adequate constructie van concept maps. Bovendien werd geconcludeerd dat de OLS voor gedragsbiologie, bestaande uit verschillende praktijken, leerlingen uitnodigt om hun kennis te recontextualiseren.

Adequate reflectie- en kennisconstructie-instrumenten, zoals concept maps en het schrijven van een essay, kunnen zorgen voor transitie van kennis als verworven kennis in een gedidactiseerde praktijk adequaat en functioneel gebruikt wordt in een andere gedidactiseerde praktijk. De analyse van de essays toonde aan dat bijna 80% van de leerlingen refereerde aan één of twee perspectieven op gedrag (causatie, functie). Het perspectief van de ontwikkeling van gedrag bleef onderbelicht. De 20% van de leerlingen die niet refereerden aan een perspectief volgde de instructie van de opdracht onvoldoende op. Verder laten de resultaten zien dat leerlingen in staat zijn om te argumenteren vanuit het gezichtspunt van een gedragsbioloog. Leerlingen gebruikten de meeste gedragsbiologische begrippen op een juiste manier. Een verandering van biologisch organisatieniveau (van organisme naar populatie) lijkt niet problematisch te verlopen.

Recontextualiseren is een noodzakelijke voorwaarde voor een correcte uitvoering van de essay-opdracht en de conclusie kan getrokken worden dat de OLS recontextualiseren bevordert. Het blijkt dat de constructie van een concept map en het uiteindelijke essay afhangen van de voorkennis en de begripsvorming. Het lijkt er op dat hoe meer betekenisvolle verbindingen een leerling in een concept map toont, hoe beter hij of zij een schrijfopdracht uitvoert. Gebaseerd op de analyse van de essays werden drie belemmeringen voor het recontextualisatieproces beschreven.

We vergeleken de actuele leeropbrengst met de leerdoelen. Geconcludeerd werd dat de OLS leidde tot het begrip van de gedragsbiologische concepten. Leerlingen onderscheidden de perspectieven op gedrag niet expliciet, maar gebruikten de gedragsbiologische begrippen op de juiste manier.

10. Discussie en conclusies

In hoofdstuk 1 werd beargumenteerd dat de volgende onderzoeksvraag moet worden beantwoord: *"Wat zijn de karakteristieken van een adequate onderwijsleerstrategie voor gedragsbiologie in het voortgezet onderwijs die de bewustwording van gedrag als een biologisch sleutelbegrip bij leerlingen bevordert?"*

De vraag of de bewustwording van gedrag bij leerlingen opgeroepen wordt door de OLS kan positief worden beantwoord. Leerlingen conceptualiseren de gedragbiologische begrippen in voldoende mate, en geconcludeerd wordt dat een adequate OLS voor gedragsbiologie kan worden geconstrueerd met behulp van de concept-context benadering en de probleemstellende benadering. Niettemin worden een paar aanpassingen voorgesteld om tot de uiteindelijke OLS te komen.

- Het gebruik van concept mappen als een reflectie instrument zou verbeterd kunnen worden door een meer systematische constructie van de concept maps.
- Leerlingen vonden sommige teksten in het werkboek te lang. Een aanpassing van lengte, niveau, en taal wordt daarom voorgesteld.
- De volgorde van de stuurvragen in de tweede praktijk van het bouwen van een welzijnsvriendelijke varkensstal zou aangepast moeten worden zodat een meer logische verhaallijn ontstaat.

De OLS is gebaseerd op acht ontwerpcriteria. In hoofdstuk 10 is geëvalueerd of deze ontwerpcriteria de beoogde impact op de OLS hadden.

1. De OLS voldoet volledig aan het ontwerpcriterium dat meerdere opeenvolgende authentieke praktijken gebruikt moeten worden. De praktijken waren relevant voor leerlingen, hoewel de onbekendheid met deze concept-context benadering voor gevoelens van onzekerheid zorgden. De vijf selectiecriteria voor authentieke praktijken maken duidelijk hoe praktijken in het (biologie) onderwijs gebruikt kunnen worden.

2. We concludeerden dat de aanpassing van de activiteit van een authentieke praktijk in leeractiviteiten in een gedidactiseerde praktijk geen problemen geeft. We concludeerden verder dat de OLS een leeromgeving creëert die interactie bevordert. Daarmee wordt ook aan het tweede ontwerpcriterium voldaan.

3. Het uitwerken van de probleemstellende benadering in de OLS lijkt effectief te zijn. Twee belemmeringen werden genoemd. Allereerst, gebruikten leerlingen bij het construeren van de concept maps verschillende stuurvragen. Vervolgens zouden de opeenvolgende motieven in de praktijk van het ontwerpen van een stal logischer moeten worden geordend om een doorlopende verhaallijn te krijgen. Niettemin concludeerden we dat de OLS voldoet aan het derde ontwerpcriterium.
4. Gezien het gebruik van drie praktijken voldoet de LT-strategie aan het vierde ontwerpcriterium. Echter, om het ontwerpcriterium te evalueren moet gevraagd worden of dit criterium effectief was. In welke mate hebben leerlingen geleerd te recontextualiseren? Recontextualiseren wordt beschouwd als een van de resultaten van de concept-context benadering met inbegrip van voldoende reflectie fasen. Niettemin wordt aanbevolen om het proces van het recontextualiseren zelf nader te onderzoeken.
5. De OLS voldoet aan het ontwerpcriterium dat actuele, 21e eeuwse gedragsbiologie onderwezen moet worden. Allereerst door het gebruik van hedendaagse sociale praktijken, en vervolgens ook vanwege de verbindingen die gelegd worden met de fysiologie door het uitwerken van begrippen stress en agressie in het General Adaptation Syndrome. Met het aanbieden van het stress mechanisme werd voor leerlingen ook de sociale relevantie van gedrag zichtbaar.
6. Werden leerlingen zich bewust van het complexe en dynamische karakter van gedrag? Achteraf gezien voorziet de OLS alleen impliciet in systeemdenken als een competentie om het emergente karakter van gedrag te begrijpen bevordert. Systeemdenken is in het bijzonder nodig voor de uitwerking van het General Adaptation Syndrome, omdat verschillende biologische organisatieniveaus in het stress mechanisme betrokken zijn. We concludeerden dat de OLS voor gedragsbiologie niet volledig voldoet aan het zesde ontwerpcriterium.
7. Gedragsbiologie is gestructureerd door de vier vragen van Tinbergen. Met uitzondering van de vraag naar de evolutie van gedrag werden deze vragen getransformeerd naar perspectieven op gedrag die leerlingen moeten gebruiken in hun exploratie van gedrag. Het blijkt dat leerlingen in staat zijn om de perspectieven, functie, oorzaak, en ontwikkeling, te onderscheiden. De OLS voor gedragsbiologie voldoet daarom aan het ontwerpcriterium dat leerlingen zich bewust worden van gedrag als sleutelbegrip.
8. De gebruikte praktijken betroffen het welzijn van dieren en de menselijke natuur. Daarom concludeerden we dat de OLS voldoet aan het ontwerpcriterium dat de sociale relevantie van de gedragsbiologie zichtbaar moet zijn.

Implicaties

Twee didactische thema's lijken belangrijk te zijn om verder uit te werken vanwege hun implicaties voor het biologie onderwijs: de rol van de docent en systeemdenken.

Ten aanzien van de rol van de docent zagen we drie problemen. 1. Docenten improviseerden soms op het scenario als dat voor het klassenmanagement nodig was. 2. Docenten waren niet zo bekend met de gedragsbiologische begrippen als ze zouden moeten zijn om deze adequaat te onderwijzen. 3. Docenten hadden moeite met het begrijpen van de gebruikte didactische benaderingen, in het bijzonder de eis voor een ononderbroken verhaallijn.

We kunnen de rol van de docent benaderen vanuit twee gezichtspunten: 1. Wat is de invloed van een doceerstijl, en 2. Hoe zouden docenten een ononderbroken verhaallijn kunnen construeren, gebruik makend van de gebruikte didactische benaderingen?

We concludeerden dat de OLS systeemdenken niet expliciet onderwijst, omdat de focus was op het creëren van een coherent web van begrippen. Echter, om het complexe en dynamische karakter van gedrag te kunnen begrijpen zou de stap genomen moeten worden van de constructie van coherentie naar systeemdenken. We doen daarom voorstellen voor een didactische benadering voor leren en onderwijzen van systeemdenken voor gedragsbiologie in het voortgezet onderwijs.

Al laatste geven we enkele gedachten weer over gedrag in de klas. In het onderwijs zijn we dagelijks betrokken bij leerprocessen en bij gedrag. Het lijkt een 'practical joke' te zijn om leerprocessen of gedrag te onderwijzen zonder deze geleerde lessen in de praktijk te brengen. Hoe verminderen we stress in de lessen? Welke les kunnen we leren van het stress mechanisme? Paradoxaal gezegd moeten we zowel stress situaties vermijden als wel introduceren. Het beschouwen van de klas als een dynamisch en complex systeem zou daarom de tevredenheid, motivatie en leerresultaten van leerlingen kunnen verbeteren.

Grau, theurer Freund, ist alle Theorie,
Und grün des Lebens goldner Baum.
Goethe

Dank

Een doel is een droom met een deadline. Een promotieonderzoek doen zou ik mijn 'big dream' kunnen noemen, die ontstond toen ik een bijdrage mocht leveren aan een ander promotietraject. Big, niet alleen in termen van een grote wens, maar ook termen van de benodigde tijd. Ruim acht jaar heb ik steeds het doel voor ogen gehouden: de finish. Dat was mogelijk, omdat ik het voorrecht heb gehad om te werken op het kruispunt van mijn interesses: onderzoek, onderwijs, gedrag en biologie.
Stress is een fundamenteel fenomeen in de biologie. In de afgelopen jaren heeft mijn lessenserie bij leerlingen reacties van herkenning opgeleverd. Daar ben ik blij mee, omdat het ook aantoont hoe relevant het is om te leren hoe het stress mechanisme werkt en hoe het verweven is met gedrag. Met deze studie wordt daarom een brug geslagen tussen wetenschappelijk onderzoek en het dagelijks leven. Dat geeft me voldoening en zie ik als een beloning. Deze studie was echter niet mogelijk geweest zonder de support en hulp van anderen. Hans Morélis gaf de aanzet tot dit onderzoek met de opmerking "Jij zou moeten promoveren!" Dank, Hans, voor het zetje en het spoor richting de Universiteit Utrecht.

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De eerste jaren was ook Arend Jan Waarlo als promotor betrokken bij dit promotietraject. Arend Jan, je aanpak was heel concreet. Met deze aanpak heb je me ook over een dood punt in het traject heen geholpen! Bedankt! Kerst en Arend Jan, waarom jullie het durfden te wagen met een onbekende promovendus van buiten de universiteit en een fulltime baan had, weet ik niet. Maar het is wel gebeurd.

Een belangrijke waarde van ontwikkelingsonderzoek is wisselwerking tussen de theorie en de onderwijspraktijk. Diverse collega's biologiedocenten waren bereid om mee te werken aan dit onderzoek. Ernst Adam, Dorien Farjon, Peter de Haas, Johanna Looijen, Andrea Poppe, Arjo van Vugt, en Menno Wierdsma: veel dank! Jullie medewerking en meedenken heb ik zeer gewaardeerd. Vele leerlingen waren voorwerp van observaties. Hun positieve en soms kritische reacties gaven de energie en motivatie om door te gaan. Mijn dank is ook aan de diverse scholen die gelegenheid boden om mijn onderzoek uit te voeren: Kalsbeek College (Woerden), Driestar College (Gouda), Goudse Waarden (Gouda), Jac. P. Thijssen (Castricum), De Passie (Utrecht), Krimpenerwaard College (Krimpen aan de IJssel).

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Dit promotietraject heeft mij veel inzicht opgeleverd in wisselwerking met mijn dagelijks werk als schoolleider. Niet–gedrag bestaat immers niet. Ik dank mijn werkgevers, het Driestar College (Gouda) en De Passie (Utrecht), die mij ruimte en steun gaven om dit onderzoek tot een goed einde te brengen. Ik prijs mij bovendien gelukkig met collega's op de Passie die regelmatig met belangstelling informeerden naar de voortgang en zo een stimulans waren. Zoals jullie al gemerkt hebben, delen jullie in de opbrengst!

Met liefde en dankbaarheid draag ik dit boekje op aan mijn gezin. Ruim acht jaar heeft deze studie ons gezinsleven beïnvloed. Lieve Martha, dankjewel voor al je steun. Joost, Guido en Reinder, wat zullen we eens gaan doen?

Anco

Curriculum Vitae

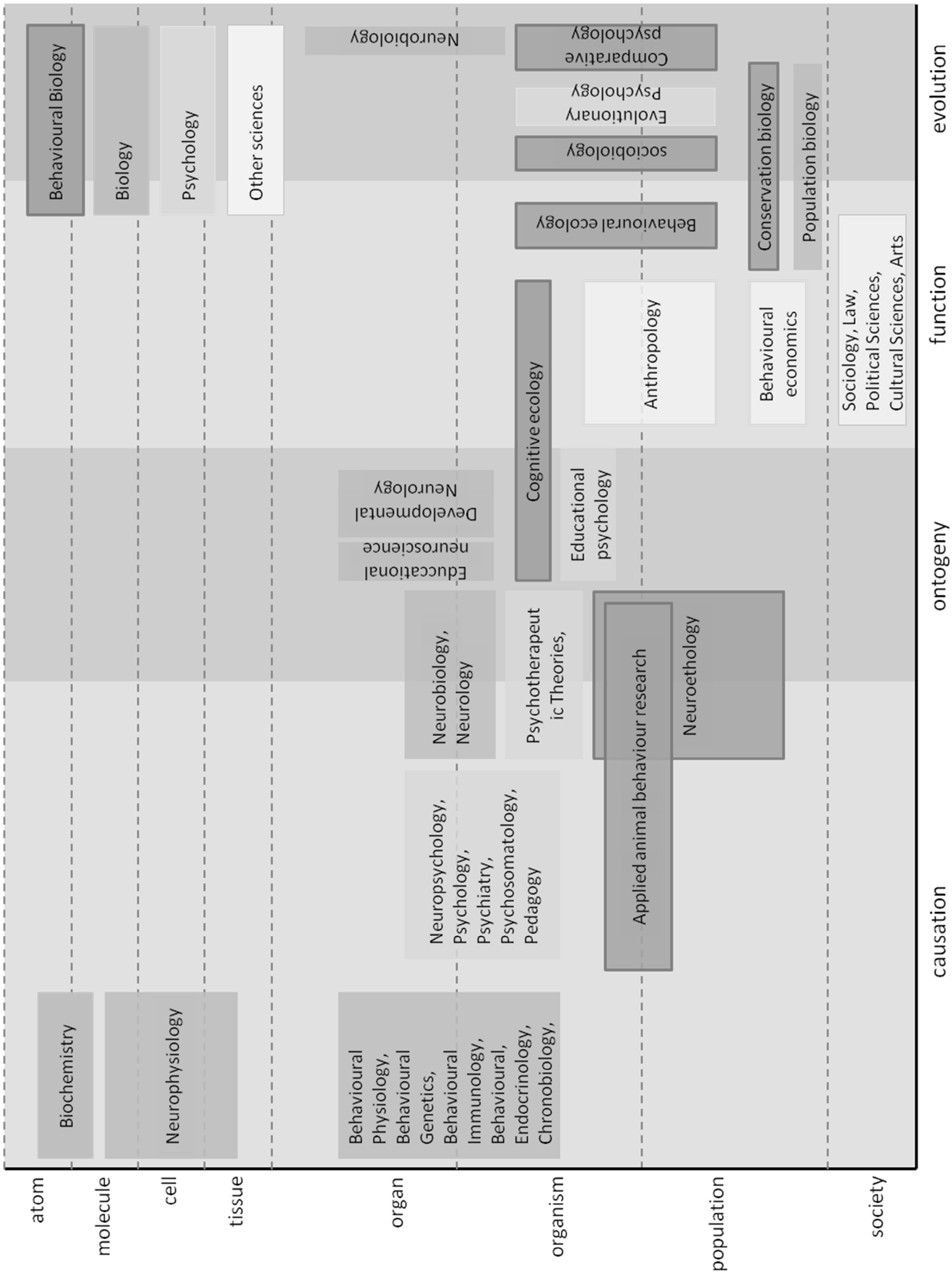
Anco van Moolenbroek was born in Scherpenisse (Zeeland) on 31 December 1968. After visiting the primary and secondary school, he moved to the Dronten University of Applied Sciences to study Dutch Agriculture. During this study Anco participated in research on forest fertilization. In addition, he did a literature survey to the preferences for a nitrogen source of tree species.

Anco got a job as researcher at the Glasshouse Crops Research Institute (Naaldwijk), where he studied on mineral balances of lettuce, roses, and carnation. He also investigated a root problem of cucumber plants.

In 1996 he became a Biology teacher at the secondary school 'Driestar College' (Gouda), and after three years of teaching, managing a department of the school was part of his job. To become a certified teacher Anco studied for Biology teacher at the University of Applied Sciences Rotterdam (2nd degree, Hogeschool Rotterdam), and at the University of Applied Sciences Utrecht (1st degree, Hogeschool Utrecht). In September 2003 he started his PhD research at the Utrecht University. In 2007 Anco went to the 'De Passie', evangelical school for secondary education (Utrecht), to be a principal.

Appendices

A Overview of scientific disciplines studying behaviour



Agressief gedrag

MC politieblad, 16 november 2008

Van onze redactie

KRIMPEN AAN DEN IJSSEL – Agressiviteit bij voetbalrellen neemt toe, waardoor steeds meer slachtoffers de dupe zijn van zinloos geweld. De politie heeft het allemaal niet meer in de hand, waardoor de gevolgen steeds erger worden. Soms dat de dood erop volgt.

Alcohol, drugs en rock 'n roll, dat willen de jongeren van tegenwoordig. Jongeren beginnen steeds vroeger met het gebruik van alcohol en drugs. Dit probleem doet zich voor doordat ouders te weinig aandacht aan hun kinderen schenken en dat scholen dit gebrek aan aandacht niet opvullen. Het gebrek aan sociale controle neemt hierdoor steeds meer toe. Daardoor krijgen de jongeren te veel vrijheid – ''ze zien door de bomen het bos niet meer'' – en kennen hun grenzen niet (ze weten niet wanneer ze moeten stoppen). Dit alles kan leiden tot agressief gedrag. In dit geval is hier sprake van zinloos geweld. Bij voetbalrellen is er ook sprake van zinloos geweld en kennen de mensen hun grenzen ook niet.

Ook ligt het probleem bij onze maatschappij. Er is te weinig politie op straat, waardoor jongeren minder gecontroleerd worden en meer risico's nemen – zinloos geweld. Een ander voorbeeld van te weinig politie op straat zijn de voetbalrellen. Voetbalrellen lopen dus al snel uit de hand. Ook kan de politie met te weinig man zichzelf niet meer verdedigen. Dit leidt tot respectloze handelingen van supporters naar politiemannen, door middel van verbale -en non-verbale agressie. Zoals het gooien van stenen en rotjes, schelden naar de politie en nog meer zinloos geweld.

Een mens probeert al vanaf zijn geboorte te overleven in een wereld die hij niet kent. Dit kan door aanpassing (adaptatie) of door je eigen weg te gaan en doen wat je nodig vindt. Ook al heeft ieder mens het dus in zich om agressief gedrag te vertonen, speelt agressief gedrag bij de één een grotere rol dan bij de ander. Een oorzaak van agressief gedrag kan dus ook gewoon bij het innerlijk van de mens zelf zitten, zonder externe prikkels. Dit zie je ook weer terug bij voetbalrellen. Mensen gaan hun eigen weg en doen wat ze nodig vinden om hun club te verdedigen. Ook is de ene supporter agressiever dan de ander. Als de agressievere supporter de ander opstookt, escaleert de boel (gevolg zijn rellen).

Ook doordat de samenleving in de loop van de tijd steeds meer groeide werd de rangorde steeds onduidelijker, waardoor individuen hun plaats niet meer wisten in de samenleving. De mens kan niet goed in grote gemeenschappen leven, want hierdoor wordt hij meer gewantrouwd, nerveuzer en voelt zich onveilig. De mens heeft het gevoel dat hij zichzelf moet verdedigen. Een vorm van die verdediging kan agressief gedrag zijn. Dus de voetbalsupporters hebben het gevoel dat ze hun club (territorium) moeten verdedigen, want ze voelen zich aangevallen door de andere club. Wanneer de politie ingrijpt, zien ze niet in dat de politie boven hen staat (rangorde). Hierdoor wordt er weer respectloos gehandeld tegenover de politie.

Ook kan agressief gedrag ontstaan bij mensen die langdurig (zware) traumatiserende ervaringen hebben ondergaan, zoals jaren gedwongen seks. Deze ervaringen kunnen voor grote problemen zorgen bij het regelen van hun agressie. Bij deze mensen lijkt het vaak of ze altijd boos zijn en misschien is dat ook wel zo. Deze boosheid wordt veroorzaakt door de angsten die bij deze ervaringen naar boven komen. Met deze angsten kunnen ze niet goed omgaan en dat wordt vertaald naar agressief gedrag. Een kleine aanleiding, zoals het verliezen van een voetbalwedstrijd, kan die boosheid nog erger maken en zo agressiviteit veroorzaken.

We hebben nu gekeken naar de oorzaken van gedrag, maar wat is nou eigenlijk de functie?

We vertonen gedrag om te overleven. Dat doen we door middel van verdediging, voedsel zoeken en ons voortplanten. Verdediging is nodig bij een zeer stressvolle situatie. Hierbij zijn er 3 dingen te doen. Vechten, vluchten en verstarren – ook wel de 3v's genoemd. Als men kiest voor vechten, dus zichzelf verdedigen in een aanvallende positie, vertoont men al snel agressief gedrag.

De functie van agressief gedrag kan ook worden veroorzaakt door roedelorde. Wie is er dominant en wie onderdanig. Niet iedereen is het daar altijd mee-eens. Dit kan dus leiden tot vechten (3v's).

Wat te doen tegen agressie en rellen? Er zijn geen directe oplossingen voor agressie, omdat we niet precies weten waar agressief gedrag vandaan komt. Agressie is wel te verminderen door middel van meer blauw op straat te zetten. De politie zal dan strengere controles bij alcohol -en drugsgebruik moeten uitvoeren.

Andere kleine oplossingen kunnen zijn: verbod op alcoholgebruik in stadia, de 'leiders' van de massa meenemen naar het bureau voor verdere maatregelen en de anderen een boete of taakstraf geven. Een andere mogelijke oplossing zou kunnen zijn dat er niet meer in grote getallen wordt gereisd naar het stadium of van het stadium. Want als er geen grote groepen zijn, ontstaan er minder snel rellen. Oplossingen om rellen echt helemaal te voorkomen zijn er nog niet, anders waren er nu ook al geen rellen meer geweest.

Wij zijn niet bekend met rellen dus kunnen wij niet goed vaststellen wat een goede oplossing zou kunnen zijn.

Waar komt het dus op neer? Er is te weinig blauw op straat waardoor rellen gemakkelijk kunnen ontstaan en escaleren. De rellen ontstaan doordat de supporters hun eigen club (territorium) willen verdedigen, dit doen ze door middel van vechten wat leidt tot agressief gedrag en zinloos geweld. Maar deze rellen ontstaan niet alleen door verdediging, maar ook omdat agressie in ieder mens zit en dat de één er meer aanleg voor heeft dan de ander. Hierdoor kan je elkaar makkelijk opstoken, omdat er ook meningsverschillen ontstaan. Om agressie een beetje in de hand te kunnen houden moet je al bij het opvoeden van het kind beginnen. Wanneer het kind niet genoeg aandacht krijgt van de ouders of van school ontstaat er een gebrek aan sociale controle. Doordat het kind zich niet in een fijne omgeving bevindt, gaat het meestal agressief gedrag vertonen. Jongeren kunnen een oplossing ook bij alcohol zoeken en dat veroorzaakt ook weer agressief gedrag. Dit kan je voorkomen als je dus meer blauw op straat zet. Er moeten strengere regels en controles komen, zodat het gebruik dan alcohol op straat wordt verminderd en zo ook agressief gedrag.

Wij zelf vinden dus dat er meer blauw op straat moet komen, in kleinere groepen moet worden gereisd (van en naar het stadium) en dat de politie ook daadwerkelijk gezag uitvoert.

Gemaakt door Chenna en Martine 4V

B2 Best sample article on aggression by students

Aggressive behaviour

MC police magazine, November 16, 2008

Editorial

Krimpen aan den IJssel - Aggression in football riots is increasing, so more and more people are victims of violence. No longer do the police have this under control, so the effects are getting worse, sometimes with deadly results.

Alcohol, drugs, and rock 'n roll, this is what the youth of today wants. Young people start getting used to using alcohol and drugs. This problem occurs because parents neglect their children and schools do not compensate for this lack of attention. The lack of social control only adds to the problem. This gives the young people too much freedom -''they don't see the forest for the trees''- and do not know their limits (they do not know when to stop). All this can lead to aggressive behaviour. In this case we are talking about senseless violence. In soccer riots, there is also senseless violence and people don't know their limits.

The problem is also with our society. There are not enough police on the streets, people are less observed and they take more risks – leading to senseless violence. Another example of too few police on the street is soccer riots. Soccer Riots get out of hand so quickly. Also, the police have too few personnel to defend themselves anymore. This leads to disrespectful acts by football supporters towards the police, through verbal and nonverbal aggression such as throwing stones and firecrackers, cursing the police and more senseless violence.

A man has been trying since he was born to survive in a world he does not know. This can be done by adjustment (adaptation) or by going your own way and doing what you like. Although every human being is in itself capable of aggressive behaviour, aggressive behaviour plays a larger role in the one than in the other. One cause of aggressive behaviour can also be simply the inner man himself, without external stimuli. This also can be seen in football riots. People go their own way and do whatever they deem necessary to defend their club. Also, one supporter is more aggressive than the other. If one aggressive supporter triggers the other, the whole thing is escalates (resulting in riots).

Also, because order in society became increasingly disrupted over time, individuals no longer know their place in society. Man cannot live in large communities, because he becomes more distrustful, more nervous, and he feels unsafe. The man feels he must defend himself. One form of defence can be aggressive behaviour. So football supporters feel that they must defend their club (territory), because they feel attacked by the other club. When the police take action the supporters do not see that the police have authority over them (ranking). This again is disrespectful to the police.

Aggressive behaviour may also occur in people who have undergone long (heavy) traumatic experiences, such as years of forced sex. These experiences may cause major difficulties in controlling their aggression. With these people it seems as if they are often or always angry, and maybe that is true. This anger is caused by the fears that these experiences bring up. With these fears, they cannot handle the situation, and that will translate to aggressive behaviour. A small situation, such as losing a football game, can aggravate anger and cause aggression.

We have examined the causes of behaviour, but what actually is the function?

We exhibit behaviour in order to survive. We do this by means of defence, foraging, and reproduction. Defence is needed in a very stressful situation. Here are three things to do. Fight, flee and become rigid - known as the 3Rs. If one chooses to fight, to defend themselves via an attacking posture, they quickly show aggressive behaviour.

The function of aggressive behaviour can also be caused by the pack hierarchy. Who is dominant and who is submissive? Not everyone agrees. This can lead to fighting (3Fs).

What to do against aggression and hooliganism? There are no direct solutions to aggression because we do not know exactly where aggression comes from. Aggression can be reduced by putting more police on the streets. The police will do stricter enforcement on alcohol and drug use.

Other small solutions may include banning alcohol in stadiums, taking the "leaders" of the supporters to the police station for further consequences, and giving others a fine or community service. Another possible solution could be that it would no longer be permitted for large numbers of supporters to travel together to the stadium. The lack of large groups leads quickly to fewer riots. There are no solutions for totally preventing riots, otherwise the riots would have already been stopped.

We are not familiar with riots so we cannot determine what a good solution might be.

So where are we now? There are too few police on the street, so riots can easily arise and escalate. The riots begin because the supporters want to defend their own club (territory). They do so by fighting, which leads to aggressive behaviour and violence. But these riots begin not only through defensive actions, but also because aggression is present in every human, and one is more prone than the next. They can easily provoke each other, because there are also differences of opinion. To control aggression you need to start with the raising of the child. When a child does not get enough attention from his/her parents or from school it results in a lack of social control. When a child is not in a good environment he/she usually shows aggressive behaviour. Young people can also seek a solution to their problems in alcohol, once again causing aggressive behaviour. This can be prevented if you put more police on the street. There must be more stringent rules and checkpoints, so that the use of alcohol on the streets is decreased and therefore aggressive behaviour as well.

Therefore, we find that there must be more police on the street, people must travel in smaller groups (to and from the stadium) and the police must actually demonstrate their authority.

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