ENGLISH SUMMARY

Introduction and overall aim

There may be many reasons to embark on the work of a thesis. My primary reason has been a wish to contribute to an improved science teaching, since there are indications that students, in schools as well as at universities, have not understood the subject matter after instruction in the way we teachers would desire. This is discouraging because in today's society everybody needs scientific knowledge in order to participate in democratic decisions and to be able to define their personal stand-points.

Since I am a teacher educator as well as a former science teacher at secondary school, I have chosen to focus on the importance of teachers in relation to the students' learning results in science. My thesis deals with teachers' competence, and in particular with what I call **competence in subject matter didactics** – the ability to teach specific groups of students in specific subject matter areas. In order to have and develop this competence it is necessary to integrate different forms of knowledge, e.g. knowledge about curricula, about students' everyday conceptions and personal knowledge about subject matter.

The overall aim of my thesis is to elucidate and discuss the teachers' competence in didactics of evolutionary biology, by looking into the knowledge of a group of teachers regarding teaching strategies, subject matter theory and knowledge about students' preconditions to learn evolutionary biology.

The conclusions will be used to discuss the opportunities which students have or ought to be provided with, in order to develop conceptual understanding. The conclusions will also be used in a similar discussion about the opportunities that science teachers have or ought to have in order to develop their competence in subject matter didactics.

Theoretical background

There are several factors that have been important to the design of the empirical study. The research tradition to which I belong made me interested in teachers' professional competence, and for me evolutionary biology was the obvious choice as subject for my thesis because of its large explanatory power. The national curriculum and its goals on evolutionary biology are of course very important. Research on students' conceptual

understanding, and the content of textbooks on this particular subject matter area is also of great interest. Several researchers have been interested in what knowledge is required in order to teach a particular subject matter area, and their studies have been important, as well as studies concerning science teachers' professional competence and their teaching.

The research tradition to which I belong

I work within a research tradition which initially focused on students' learning of different subject matter (Driver, 1981), and which has gradually widened its horizons to also include socio-cultural aspects of learning. (Driver et al., 1994; Leach & Scott, 2003). This tradition has been very productive in the field of science education. It has produced useful results when developing science teaching in schools, writing textbooks and educating future teachers. A major contribution has been close investigations of students' scientific knowledge in different subject matter areas (Nussbaum, 1979; Brumby, 1984; Mintzes, 1984; Andersson, 1986; Vosniadou & Brewer, 1992). Studies of teachers' knowledge and teaching strategies of different subject areas have also been made (Abd-El-Khalick & Boujaoude, 1997; Stigler & Hiebert, 1999; Beeth & Hewson, 1999). These results has given rise to research where different teaching strategies have been tested in order to improve the students' learning towards a more profound scientific understanding (Bishop & Anderson, 1986; CLIS, 1987; Andersson & Bach, 1996; Bach, 2001; Hagman et al., 2002; Hind et al., 2003).

Evolutionary biology has a large explanatory power

Modern evolutionary biology is a knowledge domain created by humans in order to describe, explain, predict and help us understand the course of events in the nature. Evolutionary theory is a fundamental part of biology and it explains the diversity and evolution of life out of a common origin (e.g. Ridley, 1996; Futuyma, 1998).

The usefulness of evolutionary biology becomes apparent when you want to explain the characteristics of living organisms, e. g. seals' capacity for holding their breaths underwater for a long time.

> Seals can remain underwater without breathing for nearly 45 minutes as they hunt for fish. How would a biologist explain how the ability to not breathe for long periods of time has evolved, assuming their ancestors could stay underwater for just a couple of minutes? (Settlage, 1994)

There was an individual variation in an early seal population concerning the capacity of remaining underwater without breathing. This variation had at least to some extent ge-

> netic causes. Under the prevailing environmental circumstances (food supply, competition, climate etc.) it was advantageous to be able to remain underwater during a long period of time (they could catch more fish). These circumstances lead to natural selection on this capacity, i.e. those individuals capable of remaining underwater without breathing longer than others had better possibilities of surviving and breeding, and by that pass on their genes to the next generation. In the course of time the number of seals able to remain underwater for a longer period of time increased and the genes involved became more frequent in the seal population. This selection continued during many generations, and as long as it is an advantage for seals to remain underwater during a long time the ability will continue to evolve towards intervals of even longer time. One may say that the seal population through repeated selection in a specific environment has become better adapted to this environment. The capacity to remain underwater without breathing is called an adaptation.

The explanatory text above contains a number of scientific concepts. These concepts, and others, are important in evolutionary biology. There are some concepts that are particularly important if you want to use evolutionary biology in order to explain natural phenomena, e.g. genetic inheritance, genetic variation, (natural) selection, adaptation and speciation. Unsuccessful attempts to give scientifically based explanations to evolutionary phenomena are often caused by insufficient understanding of these concepts.

Evolutionary biology in Swedish national curricula

The major explanatory power of evolutionary biology has attracted attention not only from biologists and those interested in biology, but also by those responsible for national curricula in Sweden (Utbildningsdepartementet, 1994; Skolverket, 2000). My interpretation of the formulations in the curriculum is that the concepts, models and theories of evolutionary biology should be essential in science teaching, and should also be linked to observations of natural phenomena.

Conceptual understanding and everyday conceptions in evolutionary biology

There are quite a number of research findings about how students in schools and in universities understand evolutionary biology before and after lessons in this subject matter area (Good et al., 1992; Thomas, 2000; Ferrari & Chi, 1998; Bizzo, 1994; Jiménez Aleixandre. 1992; Greene, 1990; Tamir & Zohar, 1991; Brumby, 1984; Campbell & Mitchell, 1998; Halldén, 1988; Bishop & Anderson, 1990; Wood-Robinson, 1994, Engel Clough & Wood-Robinson, 1985b). Some important conclusions from these studies are that many students…

- say that evolution has an aim or a purpose,
- do not understand the meaning of concepts like fact, hypothesis and theory,
- are not aware of the organisation levels in biological evolution,
- express that acquired characteristics can be inherited,

- do not use the concept of variation in their explanations about evolution,
- use “plausible macro mutations” or the need or desire of individuals/species, when they explain evolution of advantageous characteristics,
- say that evolution of a characteristic is influenced by the utility of the characteristic,
- explain the diminution of a characteristic with that the individual or species do not need it any more or that the characteristic is not being used,
- use the concept adaptation with its everyday meaning (that individuals adapt more or less momentarily) when evolutionary adaptation is explained,
- can not explain genealogy between groups of organisms.

Evolutionary biology in textbooks

Textbooks are an important source of knowledge to both students and teachers, and it is therefore important that the content is presented in a way that is accessible to the reader. Some researchers have analysed the content about evolution in textbooks, and a many of them call attention to shortcomings and inaccuracies:

- Central concepts like variation, natural selection, adaptation, evolution, speciation, population, time, randomness, are sometimes not mentioned at all or very briefly (Jeffrey & Roach, 1994; Linhart, 1997).
- Inaccuracies about the mechanisms of evolution occur, for example deterministic reasoning and teleological and anthropomorphous explanations (Jiménez Aleixandre, 1994; Zetterqvist, 1999).
- Connections between evolutionary theory and the phenomena that the theory is to explain are few or missing (Jiménez Aleixandre, 1994; Linhart, 1997).
- Scientific concepts like fact and theory, and connection between evolutionary biology and religion are not discussed at all or very briefly (Rosenthal, 1985; Swarts et al., 1994).
- Evolutionary biology is marginalized both in extent and placing in textbooks (Zetterqvist, 1995; 1999).

Teachers’ professional competence in teaching a subject matter area, what should it look like?

Teachers’ professional competence is essential for the students’ learning. But what kind of competence is required when students should learn a specific subject matter content? Many researchers have discussed this topic since the 1980s, among them Lee Shulman and his research team (Shulman, 1987; Wilson, Shulman & Richert, 1987). They have elaborated a ”professional knowledge base of teaching”, including the following knowledge areas:

- Content knowledge
- Pedagogical content knowledge
- Curriculum knowledge
- General pedagogical knowledge
- Knowledge of learners and of their characteristics
- Knowledge of educational contexts
- Knowledge of educational ends, purposes, and values.

The knowledge base opened up to a discussion on what kind of professional competence a teacher ought to have in order to teach a specific subject matter area, for instance by defining the concept ”pedagogical content knowledge”, which according to Shulman (1987) “identifies the distinctive bodies of knowledge for teaching”. Shulman presents three aspects of PCK:

- Methods to represent the subject matter that makes it comprehensible to others; analogies, illustrations, examples, demonstrations etc.
- An understanding of what makes the learning of specific topics easy or difficult, i.e. the preconceptions and misconceptions that students of different ages and background bring with them to the learning.
- Strategies that are fruitful to challenge and help students reorganise their understanding, since they don't come to school as white sheets.

Researchers in the Nordic countries have also shown interest in defining teachers' professional competence. Some knowledge domains where teachers' professional competence have been discussed are: didactics (Kroksmark, 1989), professional didactics (Marton, 1983; 1986b), didactics of subject matter theory (Kilborn, 1989), theory of variation (Marton & Booth, 1997; Bowden & Marton, 1998), subject matter didactics (Andersson, 2000; Sjøberg, 2000) and theory of subject matter didactics (Löwing, 2002).

There are many similarities between the models and concepts that have been used since the 1980s to discuss the competence that is required to teach a specific subject matter area (Geddis, 1993; Grossman, 1988; Marks, 1990; McEwan & Bull, 1991; Fernandez-Balboa & Stiel, 1995; Cochran et al., 1993; van Driel et al., 1998; Tullberg, 1997; Andersson, 2000; Sjøberg, 2000; Löwing, 2000). The concept of PCK has been discussed and developed by several researchers. My interpretation of these discussions is however that many definitions of PCK are too narrow to be useful.

Drawing on this, I find that a concept is needed to elucidate the specific knowledge that is required in order to teach and to develop teaching in a specific subject matter area in a specific group of students. I call this knowledge **competence in subject matter didactics**. So as to have and develop this competence I am of the same opinion as Cochran et al. (1993) that it is necessary to integrate knowledge from different areas. On the basis of the works of Andersson (2000), Shulman (1987), Wilson et al. (1987) and Cochran et al. (1993) I have identified a number of relevant areas of knowledge that make up a **knowledge base of subject matter didactics** (table 1).

Table 1: A knowledge base of subject matter didactics.

KNOWLEDGE AREA	KNOWLEDGE OF

Subject matter	• The scientific structure and conceptual content of the subject matter.
Theories of learning & knowledge	• Theories of learning and knowledge, which to some extent are relevant regardless of the subject matter taught.
Curricula and syllabuses	• Official documents describing and specifying aims of the subject matter area at hand and those related to it, so that relevant connections can be made.
Frame factors	• Practical restrictions that effect the teaching, such as time, number of students in the group, equipment for experiments and other means.
Textbooks	• The content of textbook and to be able to make comparisons between different textbooks and to look into them with a critical eye.

Table 1 continued: A knowledge base of subject matter didactics.

KNOWLEDGE AREA	KNOWLEDGE OF
Students' preconditions to learn	• Students' everyday conceptions, qualifications and difficulties to understand the subject matter content as well as related subject matter, together with their general knowledge and maturity in relation to learning and motivation.
The teacher's preconditions to teach	• The teacher's personal preconditions to teach the subject matter. Knowledge about personal strong and weak points as a basis for possible measures, like further studies or guidance.
Teaching strategies	• How to define the teaching aims and how to analyse, prepare and structure the subject matter based on personal understanding and on a judgement of what is important and what is less important. • How to present central ideas in the subject matter area by means of analogies, metaphors, examples, demonstrations and other types of explanations. • Relevant teaching methods to facilitate for the students to understand the central ideas in the subject matter area. Methods such as lectures, group work, problem-solving, experiments, homework. • How to adapt the subject matter content to match the students preconditions, like their preconceptions, everyday conceptions, and other difficulties, language, culture, motivation, social status, sex, age, capability, talent, interest, self-confidence.
Evaluation	• Different methods to evaluate the students' knowledge and the teaching goals, as well as how the evaluation results can guide and improve the teaching.

Research on science teachers' professional competence in different areas of science teaching

Several studies on science teachers' professional competence indicate that teachers may have limited subject matter knowledge as well as of different teaching strategies, of the students' preconditions and of evaluation. However, further education of teachers aiming at developing their knowledge of these areas has led to good results.

Research in teachers' and future teachers' knowledge of the structure and conceptual content of science indicate that they have the same kind of everyday conceptions as students – but to a smaller extent (Lederman, 1992; 1999; Gallagher, 1991; King, 1991; Sanders, 1993; Cochran & Jones, 1998; Tullberg, 1997; Summers et al., 2001; Ekborg, 2002). The conceptual understanding also seems to influence the teaching, e.g. the more knowledgeable teachers more often detect and challenge the students' everyday conceptions, and also they focus their teaching on understanding the subject matter content rather than on reproducing facts (Hashweh, 1987; Berliner, 1987; Sanders et al., 1993; Clermont et al., 1994).

Several studies indicate that teachers' decisions in the classroom are not primarily based on the subject matter, but more on considerations concerning practical factors (Carter & Doyle, 1987; Bromme, 1987; Emanuelsson, 2001). Teacher students and teachers do not seem to know much about the students' everyday conceptions either (Abd-El-Khalick & Boujaoude, 1997; Nussbaum, 1981). Observations of exemplary science teachers point at certain elements that result in successful teaching. For example, when planning lessons they use the students' everyday conceptions as a starting point with the aim that the students will develop conceptual understanding. They also make sure that the students are well informed about their own conceptual understanding and progress (Garnett & Tobin, 1988; Beeth & Hewson, 1999).

The evaluation of further education courses where one have made use of the students' or the teachers' everyday conceptions indicate that teachers afterwards improve their knowledge in subject matter theory and their teaching strategies, which often become more focused on conceptual understanding (Smith & Neale, 1989; Mason, 1992; Shymansky et al., 1993; Geddis, 1993; Summers & Kruger, 1994; van Driel et al., 1998). It seems as if awareness of students' everyday conceptions is particularly motivating when it comes to develop the teaching (Jones et al., 1999).

COMPETENCE IN DIDACTICS OF EVOLUTIONARY BIOLOGY

Despite the fact that the interest in teaching evolutionary biology has increased since the beginning of the 1990s, there are few studies about teachers' professional competence in this field. Several of the studies nevertheless indicate that there are uncertainties regarding the concept "theory", which many think is the same as opinion (Rutledge & Warden, 2000; Bloom, 1989; Smith et al., 1995). Some of the studies also show the existence of limited biological knowledge, inadequate comprehension of time as well as signs of "lamarckistic reasoning" (Jiménez Aleixandre, 1994; Zuzovsky, 1994; Trend, 2001; Tamir, 1992). One survey indicates that teachers as well as teacher students have insufficient competence in identifying their students' everyday conceptions (Jiménez Aleixandre, 1994). A couple of other surveys indicate that evolutionary biology is not regarded as an important teaching area since relatively short time is spent on it, and the focus does not seem to be on conceptual understanding (Jiménez Aleixandre, 1994; Shankar & Skoog, 1993; Zetterqvist, 1998a; 1998b).

Aim and issues

In the light of the great explanatory power of evolutionary biology, Swedish national curricula and earlier research results concerning students'

conceptual understanding, textbooks of biology and teachers' professional competence, I wanted to investigate teachers' competence in didactics of evolutionary biology. A complete investigation e.g. according to table 1 would be very extensive, hence I have chosen to focus on the teachers' knowledge of teaching strategies, their knowledge of subject matter, and of students' preconditions to learn evolutionary biology. Since data was generated through interviews, the aim and issues of my thesis have been specified accordingly.

The aim is to study and elucidate the competence in didactics of evolutionary biology in a test group, as it is manifested in qualitative research interviews. The research questions I seek to answer are the following:

1. How do teachers describe their teaching strategies in evolutionary biology?
2. Do the teachers express everyday conceptions? In that case, which?
3. What knowledge concerning the students' preconditions to learn evolutionary biology do teachers express?
4. Are there correlations between the teachers' descriptions of their teaching strategies, their knowledge of students' preconditions to learn evolutionary biology and possible everyday conceptions?
5. Are there correlations between what the teachers' express during the interview and the length of their academic studies and teaching experience in biology.

Methods and accomplishment

Generating data

I use the qualitative research interview as a method when generating data to answer the research questions of my thesis. I estimated that an interview of one hour with each teacher in the test group would give me a good idea of their competence in subject matter didactics.

INTERVIEW GUIDE

With the preliminary aims and issues in mind I designed an interview guide drawing on my earlier pilot interviews, and on questions used by Jiménez Aleixandre (1994) and Sanders (1993). The following questions became objects of analysis:

1. Do you teach biological evolution? Why?
2. Do you think it is important for students to know anything about biological evolution? Why?
3. What do you regard as important knowledge? Give some examples.
4. Is your teaching in this area concise or extensive? How many lessons?
5. When do you teach evolution? What form during 7-9?
6. How do you organise your teaching, lesson by lesson?
7. How do you present the subject matter content? What do you say?
8. Do you teach the following concepts in connection to evolution: genealogy, diversity, variation, natural selection, adaptation, speciation? If so, how?

9. Do the students understand the subject matter content? Do you inquire to find out if they do? How?
10. What kind of difficulties do the students have concerning the subject matter content? How do you deal with that?
11. This question was asked to a number of students:
Biologists have warned doctors against the increasing use of antibiotics for treating minor illnesses. Explain why?

What do you make of the following answer from a student?
The more antibiotics we use, the more the bacteria try to adapt themselves to be able to live with the antibiotics. At last the bacteria have survived the antibiotics and have become resistant to the antibiotics.

12. What would be an acceptable answer to the following question from a student in the ninth form?
The giraffes have, as you know, very long necks. How do you explain the evolution to long necks from their ancestors' shorter necks? Explain in detail.
13. What do you make of this text (quotation from a textbook in biology)?
Quite similarly to the plants it was difficult for the animals to leave their water life and start living on land. Slowly they changed in order to be able to live on land. The fish fins became elongated with long stalks making it easier to crawl on land. During the millions of years of evolution, the gills of the waterliving animals were replaced with lungs and other respiratory organs. They evolved legs to make it easier to move. The skeleton became more strongly built to manage carrying the body on land.

THE TEST GROUP

The selection of the teachers in the interview group was directed by my wish to get a good picture of the competence in subject matter didactics. The participating 26 teachers were science/biology teachers in secondary school, teaching forms 6 to 9, and they used to teach evolutionary biology. These teachers were not chosen at random, instead 20 schools in different districts in the Gothenburg region were contacted and the most experienced teachers were primarily chosen.

THE INTERVIEWS

A few days before the interview took place the teachers received information about the content of the interview and the questions, to give them an opportunity to reflect on their answers. Most of the interviews were carried out at their respective schools. Each interview lasted about an hour and were recorded on a cassette tape-recorder.

The analysis of the data

After transcribing and checking the interviews I used only the transcriptions for the further analysis. With the aim and issues of my thesis in mind, I constructed the following questions for analysis:

1. What teaching goals in evolutionary biology does the teacher describe?
2. How does the teacher describe the way that the teaching has been organised?
3. How does the teacher describe his/her teaching of evolutionary biology?
4. How does the teacher describe his/her teaching of a) genealogy, b) diversity, c) variation, d) natural selection, e) adaptation, f) speciation?
5. How does the teacher use of following concepts: a) natural selection, b) adaptation, during the interview?
6. What view on the scientific status of evolutionary biology does the teacher express?
7. What knowledge of the students' preconditions to learn does the teacher express?

All transcriptions were thoroughly prepared in relation to all seven questions and the wording of relevance to the question was indicated. Then the teachers' statements concerning each question was summarised in a text where I, as far as possible, used the teacher's own wording as well as several quotations.

The next step in the analysis was to look for similarities and differences in the summaries of the answers to each of the questions. The patterns that I noticed were then organised into category systems.

STATISTICAL ANALYSIS

Some descriptive statistical analyses were carried out on the basis of the results from the qualitative analyses. Frequency distributions for different questions were made, and some correlation coefficients between different variables were calculated (Kendalls Tau b).

Generalisations

Since the results are based on 26 interviews with a group of teachers not chosen at random, questions must be asked concerning generalisation and application. The generalisations that I make consist of summaries and categorisations based on my interpretations of the teachers' statements, and some statistical analyses based on my categorisations. I regard these generalisations as closed, thereby referring to a specified set of events and without extrapolation to similar events (Bassey, 1981). Hence, my generalisations are descriptive but not predictive. However, closed generalisations may be useful if the reader is capable to relate to them.

The usefulness that I claim, requires a reader who is active and competent in subject matter didactics. Such a reader should be able to estimate the plausibility of the generalisations that I have made. I have tried to present and discuss the results in such ways that the reader would, to some extent, be able to control their validity as well as relate to the results out of personal experience.

Ethical dilemmas

In a study like mine it is common to inform the participants, about the aim, method and consequences of the inquiry. But as Eisner (1998) points out, it is difficult to predict what interview data will look like, and consequently it is difficult for the interviewed persons to know what they are giving their consent to. The teachers in my test group were told that I was going to write an essay about the teaching of evolution, and that I wanted to show the variation, if any, in the test group. My impression was that

everybody considered it to be an interesting study, and that they therefore were happy to share their experiences with me.

All teachers in my thesis are anonymous. Names of places, schools and persons have been replaced with xx in the given quotations. Therefore I consider it unlikely that any of the teachers would be identified by means of the quotations.

Since my study concerns teachers' competence, there is a risk that the outcome will be interpreted in terms of "good" or "bad" teachers. Even if this is not my intention, this may harm both individual teachers and the group. This risk is difficult to avoid unless you intentionally omit research results. I consider however, that the risk of negative effects is relatively small, both for separate persons and the group as a whole. One reason is the confidentiality. Another reason is that I discuss and problemize the opportunities teachers have to develop their competence.

Results

The main results from the original analysis of the interview transcripts can be summarized in the following paragraphs:

- Quite a lot of the teachers in the test group (21 of 26) teach evolutionary biology only during form nine, most of them (17 of 26) only during the last term of Swedish compulsory school.
- Between 2-18 lessons with a teacher (one lesson = 40 minutes) were used to teach evolutionary biology. The median is 6 lessons with a teacher.
- Most of the teachers (22 of 26) say that they teach about natural selection, but only a few of them (5 of 22) say that they make explicit connections between genetic variation and natural selection in their teaching.
- None of the teachers say that they explain how adaptations evolve, but some of them (6 of 26) make some connections between adaptation and natural selection, evolution or long time.
- A small number of teachers (9 of 26) say that they teach about speciation and give examples of speciation.
- Several teachers express everyday conceptions when they use the concepts of natural selection (6 of 26) and adaptation (10 of 26) during the interview.
- Among the teachers who express an opinion about how they view the scientific status of evolutionary biology, almost half of them (7 of 20) consider evolutionary biology to have a low explanatory power and/or low scientific status.
- There are several teachers (9 of 26) who do not comment on the everyday conceptions concerning natural selection and adaptation in a written answer from a student.

In the following three sections the research questions 1-3 are answered, by bringing together and showing the central features (as I interpret them) of the teachers' statements about their teaching strategies, their everyday conceptions, and their statements about students' preconditions to learn evolutionary biology.

Teaching strategies in evolutionary biology

On the basis of the teachers' descriptions of their teaching I discern two different teaching projects*: **orientation** and **conceptual understanding** (table 2). Orientation comprises that evolution has occurred and still occurs, along with descriptions of evolution, where proofs of evolution and its chronology may be included. The concepts genealogy, diversity and variation are not linked to the teaching of evolution, and the concepts natural selection, adaptation and speciation are not taught or only briefly defined. Several teachers in the testgroup describe their teaching according to this teaching project.

Conceptual understanding as teaching project comprises how evolution has occurred and still occurs, where the mechanisms of evolution are in focus. The concepts genealogy, diversity and variation are connected to the teaching of evolution, and the concepts natural selection, adaptation and speciation are taught aimed at conceptual understanding. Only a few teachers in the test group describe their teaching according to this teaching project.

Table 2: Differences between the teaching projects **orientation** and **conceptual understanding**, based on the teachers' descriptions of their teaching of evolution.

ORIENTATION	CONCEPTUAL UNDERSTANDING
Only orientating goals and orientating elements of subject matter content in the teaching of evolution.	Goals of understanding are important, and explanatory elements of subject matter content are included in the teaching of evolution.
No connections to evolution when genealogy, diversity and variation are taught.	Connections to evolution when genealogy, diversity and variation are taught.
No teaching of natural selection at all, or teaching of natural selection only focused on the survival of individuals.	Students' everyday conceptions are challenged, and variation, reproduction and survival of genes are focused when natural selection is taught.
Adaptation is not explained during the teaching of evolution.	Adaptation is explained during the teaching of evolution.
Speciation is not explained during the teaching of evolution (unless students ask questions about it).	Speciation is explained during the teaching of evolution.

* Halldén (1988b) use the term "learning project" about students' interpretations and accomplishment of school assignments. He shows that the students interpret the assignments depending on what learning project they have. The students' learning project can also be expressed in terms of her/his intentions with the assignment or even the education as a whole. These intentions don't have to be "conscious". With inspiration from Halldén I use the term "teaching project" about teachers' (spoken or unspoken) intentions with the teaching of a subject matter area (as I interpret them during the interview).

Everyday conceptions

During the interviews the teachers' knowledge of subject matter theory in evolutionary biology is manifested in different ways. Almost half the test group (12 of 26) express everyday conceptions when they use both or one of the concepts natural selection and adaptation. The following were common:

- Natural selection is expressed in terms of plausible mutations or in terms of that individuals change in order to survive.
- Adaptation is expressed in terms of that individuals adjust themselves to the environment.
- Evolutionary biology is regarded as having little explanatory power or low scientific status.

Knowledge of students' preconditions to learn evolutionary biology.

Several interview questions were meant to investigate what knowledge the teachers have about students' preconditions to learn and understand evolutionary biology. I discern two different focuses when the teachers speak about the students' difficulties to understand. Some teachers focus on students having difficulties to understand that evolution has occurred and still occurs, and several teachers focus on students having difficulties to understand the mechanisms of how evolution occurred and still occurs (table 3).

Table 3: Two different focuses based on the teachers' descriptions of students' preconditions and difficulties to learn evolutionary biology.

FOCUS ON THAT EVOLUTION OCCURRED/STILL OCCURS	FOCUS ON HOW EVOLUTION OCCURRED/STILL OCCURS
Examples given of students' difficulties to understand evolutionary biology concern definitions of general concepts, religious hindrance or that humans have evolved.	Examples given of students' difficulties to understand evolutionary biology concern time-aspects and mechanisms of evolution.
Do not comment on everyday conceptions about evolutionary mechanisms in a written student response.	Comment on everyday conceptions about individuals' want/need and capacity to adapt in a written student response.
Only general comments on a citation from a biology textbook that contains formulations that can be interpreted as if individuals want/need or some purpose is the driving force of evolution.	Comment that formulations in a citation from a textbook can lead to students' misconceptions about time and that individuals want/need or some purpose is the driving force of evolution.

Correlations

The research questions 4 and 5 are about correlations between the teachers' statements during the interview and their background. The results from the correlation tests can be summarized in the following three paragraphs:

- Teachers with the teaching project conceptual understanding to a greater extent express good knowledge about students' preconditions to learn evolutionary biology and to a lesser extent express own everyday conceptions in evolutionary biology.
- Teachers with more academic points in biology to a greater extent give wording to the teaching project conceptual understanding, show good knowledge about students' preconditions to learn evolutionary biology, but can still express everyday conceptions in evolutionary biology.
- Teachers with long experience in teaching biology to a greater extent give wording to the teaching project conceptual understanding, to a lesser extent express everyday conceptions in evolutionary biology, but not necessarily show good knowledge about students' preconditions to learn evolutionary biology.

Discussion

Limitations

There are limitations to the usefulness of the results in my study. The results refer to the knowledge teachers have expressed during the interviews, and not to the knowledge used in the teaching situation. There are also limitations regarding the analyses leading up to the results. The analyses are accomplished by one person, even if they have been discussed with others.

Valuation and possible explanations to the results

The descriptions made by the test group about their teaching of evolution indicate that many teachers do not teach in a way which gives the students opportunities to develop the type of conceptual understanding that is required in order to explain for instance the seal issue above. Why is it so? There are several possible explanations, and I will discuss three of them here:

- The curriculum in biology is not focused towards conceptual understanding and therefore teachers can not be expected to teach in that direction.
- The textbooks in biology do not give teachers enough support to teach with an aim towards conceptual understanding.
- Teachers do not have the competence required to teach evolutionary biology with an aim towards conceptual understanding.

THE NATIONAL CURRICULUM

The Swedish curriculum in my view supports a teaching of evolution aimed at conceptual understanding. Consequently it is probably not the formulations of the curriculum that is the main explanation for teachers choosing not to teach evolutionary biology focused on conceptual understanding.

TEXTBOOKS IN BIOLOGY

There exists no thorough analysis of whether the chapters concerning genetics and evolution in Swedish textbooks may support the teachers to teach evolutionary biology with an aim towards conceptual understanding. My reading through the text about evolution in five modern textbooks (while waiting for a more thorough analysis) indicates however, that there are substantial differences between the books. One is singled out by having thoroughly included variation and natural selection, as well as many questions for students which may support a teaching aimed at conceptual understanding. Two textbooks may give teachers some support as well, among other things owing to good explanations regarding natural selection and speciation. The content in the other two textbooks does not give teachers any backup in that regard.

The presentation of evolutionary biology in textbooks could therefore explain why teachers choose not to teach evolutionary biology focused on conceptual understanding.

TEACHERS' COMPETENCE IN SUBJECT MATTER DIDACTICS

Is it possible that teachers do not have the competence required to teach evolutionary biology with an aim towards conceptual understanding? In discussing this, I have used the knowledge base of subject matter didactics (table 1) as a starting-point to define the necessary aspects of knowledge when teaching evolutionary biology aimed at conceptual understanding:

- The scientific character and conceptual content of evolutionary biology.
- Theories regarding teaching and knowledge, in order to design a teaching of evolution with an aim that students develop conceptual understanding.
- The formulations in the national curricula concerning evolutionary biology, biology and adjacent subjects, such as geology.
- The significance of frame factors, e.g. effects of teaching evolution as the last biology course in compulsory school, or effects of integrating evolution with other subject matter areas of biology.
- Evolutionary biology and content of adjacent subject matter in appropriate textbooks.
- The students' everyday conceptions and their preconditions and difficulties to understand evolutionary biology and adjacent subject areas.
- Personal preconditions to teach evolutionary biology, and knowledge concerning strong and weak points in order to be able to develop the competence in an appropriate way.

- How to design the teaching of evolution on basis of curriculum goals, personal teaching goals, central ideas in evolutionary biology and the students' preconditions.
- Relevant explanations and teaching methods aiming at students' understanding of central ideas in evolutionary biology, e.g. the mechanisms of evolution.
- Different ways to evaluate the students' knowledge in evolutionary biology and to be able to use the evaluation results to improve the teaching of evolution.

In fact, my study does not look into all the above stated aspects, but into a sufficient number of the aspects and into sufficiently important ones. This enables me to conclude that many teachers in the test group do not have the competence in didactics of evolutionary biology according to the aspects described above. My results also give some indications of that an orientating teaching project is linked to an insufficient competence in subject matter didactics as depicted above.

TEACHERS' OPPORTUNITIES TO DEVELOP THEIR COMPETENCE IN SUBJECT MATTER DIDACTICS

In my view there are at least two possible explanations why many teachers do not teach evolutionary biology with focus on conceptual understanding. One is that many textbooks don't give enough support for such teaching. Another is that teachers don't have sufficient competence in subject matter didactics to teach focused on conceptual understanding. In the light of the extensive knowledge needed to have and develop competence in subject matter didactics it is not at all surprising if teachers have deficiencies regarding this competence. Furthermore teachers have not had enough opportunities to develop their competence in subject matter didactics, due to an insufficient or lacking awareness in school politics, educational research, in teacher education and at schools, of the extensive knowledge that is required to teach every subject matter area.

In educational research, only a small part has been aimed at studies which could contribute to the development of teachers' competence in subject matter didactics. The research in subject matter didactics in Sweden has existed but a few years, hence there are yet few professors, PhD's and postgraduate education in the field. Eisner (1998) and Lijnse (2000) point out the great responsibility of educational research, and others (Stigler & Hiebert, 1999; Ma, 1999; Dillon, 2000; Lumpe et al., 2000) emphasize the importance of teachers' workplaces in supporting the development of their professional competence.

When it comes to teacher education, many studies indicate that student teachers do not develop the sufficient competence in didactics of science to manage teaching aimed at conceptual understanding. This is hardly surprising since many teacher educators probably lack the necessary competence in subject matter didactics themselves; and therefore they are not able to give student teachers the opportunity to develop such competence. Several

researchers in science education, both in Sweden and other countries, emphasize that the teacher education should take on more responsibility concerning teacher students' developing of professional competence. This applies to knowledge in subject matter theory (Jungwirth, 1975; Cochran & Jones, 1998; Ekborg, 2002), as well as knowledge concerning students' preconditions to learn science (Nussbaum, 1991; Jiménez Aleixandre, 1994; Jones et al., 1999), and also knowledge about possible teaching strategies (Ma, 1999; Lager-Nyqvist, 2003).

Students' opportunities to learn evolutionary biology

A teaching of evolution that is not directed towards conceptual understanding leads to limited opportunities for many students to learn evolutionary biology. In addition, if there are deficiencies regarding the teachers' knowledge of subject matter theory as well as of students' preconditions, it is not surprising that many studies show that students have an insufficient scientific conceptual understanding and many everyday conceptions in the subject matter area.

A teaching of evolution that is focused on orientation may have the result that students merely understand <u>that</u> evolution occurred/still occurs, and can maybe <u>describe</u> parts of the history of evolution. But if they do not have developed conceptual understanding regarding variation, selection and adaptation, they will not be able to use these concepts when explaining biological phenomena (Bishop & Anderson, 1990; Wallin et al., 2000). Many teachers in my test group say that they do not teach speciation at all, which implies that students only learn how to describe and exemplify the diversity, but are not given the opportunity to understand how it has evolved. Studies by Shankar & Skoog (1993) and Jimenez Aleixandre (1994) also indicate that an orientating teaching of evolution could occur.

Zuzovsky (1994) and Jiménez Aleixandre (1994) have shown that "lamarckistic" explanations are not at all unusual among teachers and student teachers. Many teachers in my test group also express everyday conceptions, e.g. that individuals adjust to the environment. If teachers express everyday conceptions during the lessons, naturally, the result may be that students will neither have the possibility to understand the scientific concepts, nor how they should be used in order to explain biological phenomena.

Among the everyday conceptions that have been observed among teachers, some concern the scientific status of evolutionary biology (Bloom, 1989; Shankar & Skoog, 1993; Scharmann, 1993). In my test group many teachers give evolutionary biology a low scientific status and a low explanatory power. According to Rutledge and Warden (2000) the teachers' views on evolutionary biology as unscientific, could explain why the teaching of evolution gets so little space, which will influence the students'

views concerning the nature of science. Some teachers in the group place evolutionary biology on a level with the Christian story of the creation, and some let the students take position for or against the theory. The effects of a teaching strategy where students' have to choose between scientific theories and religious dogmas may result in placing science on a level with personal opinions. Students who have a religious view of life may also refrain from science, if they think that it is impossible to combine their belief in God with scientific explanations.

The teachers in the test group generally show good knowledge regarding students' preconditions to learn the subject matter content. Beeth and Hewson (1999) emphasise however, that if the teacher is going to help students to develop conceptual understanding it is necessary that the students' everyday conceptions constitute a distinctive part of the teaching, so that their conceptions may be discussed and challenged. In my test group there are some teachers who seem to explicitly make use of students' everyday conceptions in their teaching by discussing them in the classroom. If teachers do not use knowledge of students' everyday conceptions when teaching, it could explain why many students even after tuition use everyday conceptions when they explain evolutionary phenomena (Settlage, 1994; Bizzo, 1994; Wallin et al., 2001).

A knowledge base of subject matter didactics for teaching science aimed at conceptual understanding

If we want students to develop conceptual understanding in evolutionary biology and other science areas, the teachers' competence must be adjusted accordingly. My view is that by having a knowledge base of subject matter didactics (table 1) as a central theme in the science teacher education and further education of teachers, future and active science teachers will be provided with good opportunities to develop this competence.

Research in subject matter didactics

The research in subject matter didactics is about investigating and to better understand the conditions regarding teaching and learning within different subject matter areas. An important purpose is to contribute to the improvement of students' learning of school subjects. For example the research results regarding students' everyday conceptions within a subject matter area may be included in science teacher education and further education, and thereby improve the preconditions for future and active teachers to teach different subject matter areas. This may lead to their students improving their learning. Research results concerning textbooks may lead to a development of better textbooks, which may influence the students' learning both directly and as a consequence of the teacher's bet-

ter preconditions to teach. Results from teaching experiments could entice teachers to try new teaching strategies, which may benefit the students.

My thesis is a contribution to the knowledge of teaching of evolution, and to the development of teachers' preconditions to teach evolutionary biology. An important conclusion is that many teachers in my test group do not seem to teach evolutionary biology focused on conceptual understanding. Many teachers don't seem to have sufficient competence in subject matter didactics to do so. Along with Ekborgs, (2002) and Lager-Nyqvists (2003) longitudinal studies concerning student teachers and what they learn during their science teacher education, my study brings about questions on what competence future science teachers develop during their education, and how it corresponds with Swedish national curricula.

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