Clas Olander works at the Department of Education, University of Gothenburg. Drawing on a background in teaching at several levels in secondary schools his current interest is the intersection of 'practice and theory'; especially students' language use when making sense of school science.

Åke Ingerman works at the Department of Education, University of Gothenburg. His research primarily takes its starting point in pedagogical situations where students meet scientific and technological knowledge in different forms, and aims towards developing the quality of that meeting.

CLAS OLANDER
University of Gothenburg
Sweden
clas.olander@gu.se

ÅKE INGERMAN
University of Gothenburg
Sweden
ake.ingerman@gu.se

Students' language use when talking about the evolution of life - negotiating the meaning of key terms and their semantic relationships

Abstract

In this paper, we explore an idea from Vygotsky about the meaning and sense of words, and how it manifests itself in students' talk. This is done by analysing the discussions of 15-year old Swedish students participating in teaching activities concerning biological evolution. It turned out that the students seldom articulated the scientific terms. Instead, they contextualised by using three strategies – paralleling, transferring, and delimiting. All three of these strategies have merits and drawbacks in connection with 'meaning' of single terms. However, when combining the terms into thematic patterns, the students formed rather sound and coherent scientific explanations. This is understood as relying on the students' use of an interlanguage where colloquial expressions serve as an asset in sense-making. The verbalisation of an explanation in an interlanguage is advantageous when communicating in social life outside the science classroom, and thus the possibility of further sense making is enhanced.

Introduction

Biological evolution could be explained, according to Stearns and Hoekstra (2000), by recognising three conditions: "individuals must vary in reproductive success; some variation in the trait must be heritable; the trait must be correlated with reproductive success" (p. 9). If the correlation between reproductive success and trait is either positive or negative, there will be natural selection (adaptive evolution); on the other hand, if the correlation is zero, there will be no selection at all (neutral selection). A similar way of expressing evolution accentuating the important terms is presented by Wallin (2004): "the theory of evolution can rather easily be described by using three concepts: existing variation, heritage, and natural selection" (p. 261). The definition articulated by

Stearns and Hoekstra resides directly in the science community, while the definition from Wallin is closer to school science.

One of the merits of scientific language is that the meaning of terms, concepts, models, and theories are well defined and specified in the scientific community. When entering school science, these terms, concepts, models, and theories are often expressed with simplifications and delimitations. One of the challenges for school science is to explain science without sacrificing the essence of the language in science. Accordingly, exploring the meaning that students make of the scientific terms would be a way to increase understanding of the relations between science and school science, as well as between colloquial and scientific language. In this paper, this is done with reference to the distinction Vygotsky (1986) made between *meaning* and *sense* of expressions. Meaning is the stable (generalised, collective and lexical meaning) zone of an expression, while sense is more situated and dependent on the context of the talk (personal, local and creative meaning).

Learning science involves making sense of the school science language, which, according to Reveles and Brown (2008), includes the ability to contextually shift between different social languages (Bakhtin; 1981), in this case, the colloquial and scientific languages. The ability to use, translate and distinguish between social languages is one of the aims of science education and the more confidently the students move between languages the more mature is their understanding (Mortimer & Scott, 2003). When students work with making sense of the scientific language, through the use of colloquial language, they may develop a new hybrid language; an *interlanguage* (Barnett, 1992; Lemke, 1990). This interlanguage is more personal and dynamic (Gomez, 2007) and the possibility of connecting and bridging between informal and formal accounts of phenomena increases (Brown & Spang, 2008). This mixture of two social languages is used analytically in science education research when, for example, examining teaching and learning about biological adaptation (Ash, 2008) and teaching and learning about evaporation, boiling and condensation (Varelas, Pappas & Rife, 2006).

Explaining biological evolution may appear straightforward in the science community, but it is a topic that educational research has depicted as challenging for students to make sense of; the process of sense-making, in general, is assumed by Bruner (1985) to consist of conceptual, epistemological and ontological aspects. The most prevalent ontological aspects are related issues that shape our world views: for example, religion, gender, ethnicity, and ideology (cf. Cobern, 2000; Smith & Siegel, 2004). The epistemological issues that are most challenging deal with formation of explanations, for example, choosing a teleological or a causal explanation (Kampourakis & Zogza, 2008; Mayr, 2004), or the choice of biological organisation level when explaining (cf. BSCS, 1993; Zetterqvist, 1995). Examples of conceptual aspects are those mentioned above: variation, heredity, and selection (cf. Ferrari & Chi, 1998; Wallin, 2004), and also, for example, individual or population focus (Greene, 1994) or geological time (Dodick & Orion, 2003).

This paper reports an analysis of students' talk in peer group discussions in a Swedish compulsory school, a pedagogical context where activities were informed by insights from a didactical analysis of relevant scientific terms for explaining biological evolution; according to Brown and Ryoo (2008) it is the combination of conceptual and language components that enhances students' understanding of phenomena. The aim of this paper is to explore in what ways the terms serve as tools in the students' talk and in what ways the meanings of the terms are articulated. The specific research questions focus on students' use of the key terms (variation, heredity, and selection) that the teacher intended to communicate the scientific story with. Firstly, the analysis focuses the terms one by one, and secondly, it focuses on the linking between terms when construing explanations of biological evolution. Thus, the specific research questions are:

– In what ways are meanings of the key terms construed in the students' discussion?
– In what ways are key terms linked to explanations in the students' discussion?

Methods

Data collection and context

The data analysed in this paper were generated within a teaching intervention with the aim of introducing the theory of evolution as a tool for reasoning, referring to the key terms *variation, heredity, and selection*. The teaching strategy was to include many opportunities for students to explore their understanding of ideas; ideas that were introduced both by the teacher and the students. The teachers often enacted the teaching strategy as activities that included talk in peer groups, and in order to explore the students' sense-making of the key terms, recordings of students' discussions in peer groups were made, activities that were an integrated part of regular teaching. The students were approximately 15 years old and all in grade 9, which is the last year of compulsory schooling in Sweden.

Altogether 19 students in 7 groups were recorded while performing two types of activities, both of which were supposed to enhance the students' use of the theory of evolution as a tool for reasoning, and specifically the terms variation, heredity, and selection. The students' talk analysed relates to the following two activities (performed during lesson number five and six of totally nine lessons):
– discussing while working with an interactive web-based application (*predict population*)
– discussing the result of a hands-on game where students acted as predators (*selection game*).

In the web-based activity (*predict population*), pairs of students worked with an activity developed by Wallin and Andersson (2004). On the screen, the students were given written information, which they discussed and then sent a written response to a database; the database generated new information, students talked, sent new responses, etc. The analysis was performed with respect to two parts of the activity, where the first part was students' talk when they discussed the information that introduced the activity. The text on the web page was:

> During a period of a couple of days a population of reindeers was observed by a scientist. She noticed a great variation in the length of the reindeer's legs. The scientist divided the population into three groups with respect to length of legs. She saw that 20% had short legs, 60% had somewhat longer legs, and 20% had long legs.
>
> Let us now imagine that you are visiting this population of reindeers in the same area many reindeer generations later. Use what you have learnt about the theory of evolution, and speculate about the length of legs of the reindeers at this later time.

After submitting their answer to the database, the students were given new information and were asked whether they wanted to alter their previous prediction. For example, the students were informed that a population of wolves lived in the same area, and that it was easier for these wolves to hunt short-legged reindeers than the more long-legged ones. The consequences for the wolf population (of differential prey population) are the second part that is analysed. Totally, ten pairs of students carried out the activity, and five of these pairs were audio recorded when talking.

In the *selection game*, students in groups of four/five played the role of predators and tried to catch prey on a playing board. The game resembles an activity described by Stebbins and Allen (1975); however, in the version used here, the prey population consisted of paperclips in ten different colours; ten of each colour (totally one hundred clips) were spread out on a playing board. The differently coloured clips were supposed to represent a variable population of preys. Now the game started and in the first round the students picked (hunted) the clips by sight; they picked up one by one while walking around the playing board until there were twenty-five clips left. Then the clips 'reproduced', meaning that for every clip that was left on the board three more were added, thus the clip population was again one hundred individuals. Now a new round (hunting season) began and this could go on for three or four rounds (seasons). The students then sat down and tried to explain that result, for example, the distribution among the colours had changed, and there were not ten of each anymore. Some colours could be very frequent while other colours were not even present at all. The whole game with two groups were video recorded although the analysis mainly focuses on the concluding talk between students, approximately ten minutes from each of the two groups; totally nine students.

Analytical procedure

It was soon obvious that the students seldom explicitly verbalised the key terms *variation, heredity, and selection*; instead, they made several reformulations. Consequently, the interest turned towards these reformulations and the emerging structures of how the students addressed the key terms linguistically. When generating structuring tools, our first source of inspiration was Vygotsky's (1986) distinction between *meaning* and *sense* of a word. However, in this paper the 'words' we focus on (variation, heredity, and selection) have a specific use and conceptual bearing; hence, we depict them as terms. In the introduction, we referred to meaning as the stable and generalised zone of a term, while sense is more situated and dependent on the context. In this paper, our assumption is that the use of the terms in the science community is closer to the generalized meaning, and in the students' talk it is mainly the locally and situated sense that is focused on.

Analysis of the ways meanings of the key terms are construed in the students' discussion

The analytical focus has been on students' talk, instances where the students' contextualise the key terms. The function (sense) of the contextualisation, in the students' talk, in relation to generalised and collective meaning in this way becomes our main interest. For example, the students never uttered the term variation, instead they talked about differences. Likewise, they never explicitly mentioned selection and instead they talked about the consequences of how well animals 'managed' or differential rates of survival and/or reproduction. The analysis of students' talk identified and made tentative use of three strategies of sense-making (see Table 1), strategies that served as conceptual links in the students' talk, which we labelled: *paralleling*, *transferring*, and *delimiting.*

Reformulations with *paralleling* or using synonyms are made, according to Brown and Ryoo (2008), when a term (often scientific or technical) is somehow uncomfortable, partly unknown, or difficult to pronounce. A more familiar parallel word residing in everyday settings is used instead, which in turn could lead to other interpretations than were originally intended. For example, the term 'autotrophic' used in biology as science, becomes 'producer' in school science; whereas 'those that make their own food' would be a parallel in colloquial language.

When *transferring,* the unknown is connected to the known by using metaphorical expressions. The rationale is to make links in the sense of 'understanding and experiencing one kind of thing in terms of another' (Lakoff & Johnsson, 1980, p.5). When explaining something 'in terms of' (using a metaphor), it may imply other interpretations and thus have educational implications (Pramling,

Table 1. *The three strategies' relation in context, meaning, and sense.*

Strategy	**Context (relation to the task)**	**Meaning (generalized meaning)**	**Sense (function in the talk)**
Paralleling	Same	Potentially same	In the students' talk it is meant to be the same; thus, the point of departure in the analysis
Transferring	Different	Uncertain	
Delimiting	Different	Partly different	

2008). Transferring could be done using anthropomorphic metaphors, for example, like Darwin did with 'struggle for existence'; another example of Darwin's transferring strategies is the comparison between *artificial* and *natural* selection.

Delimiting the meaning is done when a term could be interpreted broadly and with different specificity and quality. Often, delimiting is done as a specification when a term has different interpretations in informal/colloquial and formal/scientific contexts. For example, when explaining biological evolution the term *adaptation* is often used (cf. Kampourakis & Zogza, 2008), in this case, a specification is essential. On other occasions, delimitation can curtail the meaning of a term, it loses nuances or even essential aspects of its meaning.

Analysis of the ways key terms are linked to explanations in the students' discussion

The second research question deals with the students' generation of explanations or, more precisely, the students' use of the key terms (sense of the key terms) in relation to each other. This linking of key terms results in a network of semantic relationships between terms, which, according to Lemke (1990), is a thematic pattern that describes the science content. Thereby, the unit of analysis changes; in relation to the first question, attention was focused on contextualisation's of single terms, while in the case of this second question, attention is focused on longer sequences of students' talk concerning negotiations of possible ways of explaining the given tasks. The two prevalent ways in which the students' negotiated explanations constituted on the one hand *discernment of differences* between terms and on the other, *linking and coherence* between terms. In both cases (discernment of differences and linking), it was also possible to explore different qualities in the students' ways of explaining.

When explaining biological evolution, a qualitatively rich answer should include, according to Ferrari and Chi (1998), five terms or components: *individual variation, heredity, differential survival, differential reproduction, and accumulation of changes*. The three latter components together frame the notion of selection; however, taken separately they could point to different understandings. Differential survival is merely a step towards the most crucial component, which is differential reproduction. The component of accumulation, which can be seen as the result of repeated selection points to a definition of evolution as the *change of gene frequencies in populations*. In this statement, selection refers to the organisation level of populations although the level of molecule (gene) is present. However, it is individuals that reproduce; hence, quality in explanations could be explored depending on the organisation levels that are used. The estimation of quality relies on the linking and relations of the components, for example, if they are articulated with a causal manner.

Findings

In this first section, the students' sense-making of the three key terms (variation, heredity, and selection) is analysed in relation to three identified strategies: paralleling, transferring, and delimiting. The general patterns that were outlined in Table 1 are specified and exemplified in Table 2. Furthermore, it should be noted that the exemplifications in Table 2 are a summary of the findings presented in connection with excerpts 1 – 10. For example, when variation (i.e. Vygotsky's meaning) is reformulated as difference (i.e. Vygotsky's sense), this is taken as an example of paralleling (excerpt 1; turn 96: `they haven't got a mutation ... it is only that they are differently tall we are different as well)`. In relation to the task, this reformulation is rather appropriate, hence paralleling. However, in relation to a generalised meaning, it is vague since difference could be understood on different organisation levels; for example, in excerpt 1 the students discuss whether the origin of the difference should be understood on the level of gene or organism.

Table 2. *Examples of the students' sense-making of the key terms. Please note that the sense of the terms (their function in the talk) is seemingly the same, judged by the conversation.*

Strategy	Example (from excerpt 1 - 10)	Context (relation to the task)	Meaning (generalized meaning)
Paralleling	Variation → difference (cf. excerpt 1; turn 96)	Same; refers to diversity in traits (length of legs and colour, respectively)	Potentially same; difference could be understood on varying organisation levels
	Heredity → disposition lives/carried on (cf. excerpt 2; turn 67)	Same; together, the words place disposition close to the term heredity	Potentially the same; refers (only) to the passive transport of genetic information
Transferring	Selection → manage (cf. excerpt 6; turn 440)	Different; manage could imply survival but not reproduction and accumulation	Uncertain; vague in relation to explanations in biology
	Heredity → lives/ carried on (cf. excerpt 8; turn 114)	Different; heredity is a process that shapes both similarity and dissimilarity	Uncertain; whether it points to shaping similarity or dissimilarity
Delimiting	Heredity → disposition (cf. excerpt 2; turn 65)	Different; since vague and ambiguous, it has to be contextualised	Partly different; there are (at least) five connotations of the word disposition
	Selection → survive, reproduce, and/or accumulate (cf. excerpt 8; turn 114/6)	Different; the model was supposed to include all three components	Partly different; choice of component(s) alters understanding

Contextualisation of variation

The term variation is written at the beginning of the text in the computer activity and in the selection game, the students are told that the paper clips varied in colour; yet the term variation is never explicitly used by the students. Instead the students talk about *differences*, which is a reformulation with a parallel word. In excerpt 1, based on computer activity, the students should speculate on whether a change over time has taken place. The students in this context interpret variation as differences, and they take change (difference over time) as their starting point; change is taken for granted.

Excerpt 1

89	Eva:	`first of all, it is a mutation that makes you get longer legs`
90	Emma:	`mm`

91	Eva:	`and since they would rather take your friend who doesn't have your mutation`
92	Emma:	`mm`
93	Eva:	`because they get hold of your friend more easily therefore you survive and your children get your dominant mutation`
94	Emma:	`mm`
95	Eva:	`the reindeers that survive are those who got the mutation`
96	Emma:	`they haven't got a mutation ... it is just that they are different heights we are different as well`
97	Eva:	`there is a reason why we are different`
98	Emma:	`so Miranda has a mutation since she is taller than us`
99	Eva:	`no, but that is what has happened`
100	Emma:	`no, her parents are tall`
101	Eva:	`it must have been a mutation that made` (predict population, group 3)

In the excerpt above, the origin of the difference (variation) is negotiated, starting out with a claim from Eva: `first of all, it is a mutation that makes you get longer legs` (turn 89): this reference to genetic reasons is in line with the school science view. However, Emma in turn 96 changes Eva's general reasoning about the origin of change into a more personal and local context `we are different as well;` exemplified with reference to a mutual class mate: `so Miranda has a mutation since she is taller than us` (turn 98). This could be seen as a negotiation on how to contextualise the explanation. Eva argues for the *ultimate* origin of variation when she claims `there is a reason that we are different` with reference to mutations. Emma finds it odd that mutations should explain the height of a mutual friend and goes for the more colloquial and *immediate* explanation `her parents are tall` (turn 100). The negotiation is somehow settled when they write the text in the database where they do not mention any genetic reasons for differences in the length of legs; they only claim that that there is a difference in the length of legs and that this difference has consequences. These consequences will be further elaborated when research question two is discussed (excerpt 8 9 and 10).

Contextualisation of heredity

The excerpt below is from the first part of the computer activity where the students are supposed to speculate about possible change in length of legs among reindeers. All three sense-making strategies are used by the students.

Excerpt 2

61	Gail:	`disposition ... gets most of the times the disposition`
62	Gro:	`no but hello`
63	Gail:	`they can only`
64	Gro:	`it doesn't matter a damn`
65	Gail:	`disposition for long legs ... and in that way it lives on (`*`silence for 20 seconds while Gail writes`*`) ... those with short legs don't survive and their disposition isn't carried on ... their sets of genes`
66	Gro:	`disposition was good`
67	Gail:	`disposition isn't carried on, stop` (predict population, group 5)

Here, heredity is first reformulated into disposition as almost a word *parallel*. However, disposition is, in turn, reformulated as something that `lives on` or `isn't carried on` (turn 65 and 67). Expressed in this *transferred* way, heredity reflects a view of passive transport of particles, which is a *delimitation* of the 'original' term heredity.

The expressions *lived* or *carried on* are metaphorical (transferred) in the sense that instead of saying inherited, the students reformulate to 'in terms of'. In this case, (in terms of) something that lives or carries on implies stability and similarity, thus the transferred sense points to the passive part of heredity, the process that causes similarity between generations (passive transport of the DNA in the gamete during fertilisation). The active process (mutations), which causes dissimilarity between generations, is thus toned down.

Furthermore, the synonymous term disposition has wider connotations, mainly in colloquial language. Consequently, the conversation in turns 65 - 67 is also a negotiation of delimitations, about how to understand what it is that actually is 'carried/lives on'. The students' label is *disposition;* in Swedish, the students' use the word 'anlag', which could be understood in various ways. In general and broad use, disposition could imply *tendency*, for example, 'tendency to put on weight' or it could refer to *talent*, for example, 'have a talent for football'. In a biology context, disposition could be a first stage or trace, *rudiment*, for example, 'rudiment of feathers' or it could refer to an *ability* (trait), for example, implying the ability to swim. However, the most frequent use in science settings is *hereditary disposition*, implying 'set of genes'. In this excerpt, the pair of students agree on the broader wording (turn 67), but the reference to 'genes' in turn 65 implies that their interpretation is close to the scientific notion.

Contextualisation of selection

The term selection is not explicitly used; instead, ways of understanding the term selection are negotiated by means of *delimitations*. Typically, students make delimitations by focusing on different components: survival, reproduction, or accumulation (cf. excerpt 3 and 8), which could be inherent in the term selection (Ferrari & Chi, 1998).

Excerpt 3

84	Eva:	`first I thought that it was like mutations and that is, of course, true, but then it is definitely also like this ... that it is those with longer legs that survive better and then it is those who reproduce`
85	Emma:	`exactly, then we write like this ... let us take the example that all reindeers are chased by wolves ... the fastest survives`
86	Eva:	`which is the one with the longest legs`
87	Emma:	`because it runs fastest, has a good mutation` (predict population, group 3)

If the survival component is distinguished, with the aspect of differential survival, then differential reproduction rate could more easily be explicitly mentioned as a consequence: `those with longer legs survive better and then it is those who reproduce` (turn 84). The discussion could also lead a few steps further as will be shown later (excerpt 8) where the students stretch the term selection to include several generations and an increase in the frequency of the gene (trait) – an example of linking to the component accumulation.

In the selection game, the students were faced with explaining change in frequencies of colour distribution among the paper clips; some colours became more frequent while other became less so. In excerpt 4, the discussion aims at explaining why there are so many light blue clips left.

Excerpt 4

222	Andy:	`they taste yucky`
223	Alice:	`they are faster`

224 Andy: they are stronger
225 Anna: they are more pleasant to the eye
226 Agnes: they are visible in relation to the background
227 Alex: I think that
228 Anna: then they should be gone
229 Agnes: the black ones are not gone I can't take it anymore
230 Andy: the blue ones have a small extra defence like a small spike
231 Anna: I think that the blue colour makes them poisonous like that Pilgrim frog, they have are so strongly coloured that you iujj
232 Alice: same thing with the red, they can be red by such mystic
233 Anna: look, there are only bright colours left
234 Agnes: look, here is one that shines and there is one that doesn't
235 Anna: which is more pleasant to the eye (selection game, group 1)

The members of the group bring up several examples of the frequent occurrence of light blue clips: they taste yucky, are faster or stronger, have a small extra defence; thus students talk about clips as eatable prey and they *delimit* the term selection to survival. All the explanations above could be regarded as a result of the students' ability to engage in the game and it is firmly situated in the context of the actual game. At one point (turn 231), there is a reference that stretches outside the actual game when Anna refers to aposematism[1] with the claim I think that the blue colour makes them poisonous like that Pilgrim frog and turn 233 there are only bright colours left. This seems plausible to Agnes since look, here is one that shines and there is one that doesn't shine (turn 234) thus taking the conversation back to the actual game. The inputs from Andy/Anna in turn 230/231 are intended to respond to the remark by Agnes in turn 226, which contradicts the 'best camouflaged explanation'. The same kind of explanation is also what the other videotaped group starts out with:

Excerpt 5

440 Bob: if we were to do it again, the orange would not manage
441 Bea: I think it has to do with which, you see it depends on the background, it is the same thing as environment
442 Bree: but if you take randomly it would not be like that ... Boris chose to take the black ones
443 Bob: if you keep your eyes closed
444 Bea: yes but if we think of it as an environment, like the savannah and then these, like, yellow-orange will... then it is better to be than like black you are more visible if you are black than if you are yellow-orange
445 Bob: but in this game it was better to be black
446 Bea: yes it was (selection game, group 2)

Here, the conversations stretch outside the specific game, when Bea makes a *parallel* between environment and background: it depends on the background it is the same thing as environment /.../ on the savannah you are more visible if you are black than if you are yellow-orange. Bob seems to agree with these claims, and refers to the actual game they were playing: but in this game it was better to be black. Such connections between the actual game and the natural world are rare in this study.

Semantic relationships between key terms in the students' discussion

First, two excerpts are given where students discern significant differences between the key terms, and by doing this they generate explanations. Examples will be given where students make coherent use of the key terms, or more precisely their sense of the key terms, as tools in order to generate explanations.

Discerning differences between key terms

In this section, the focus is on instances in the students' talk where they negotiate delicate but important nuances (differences) in wording connected to understanding *variation and selection*. Furthermore, in the students' talk there are alterations and translations between different social languages.

Excerpt 6

50	Gro:	`those reindeers with`
51	Gail:	`intermediate length of legs`
52	Gro:	`yes, longer legs`
53	Gail:	`find it easier to escape and their generations, or find it easier to escape because they then become faster`
54	Gro:	`it is rather obvious but ok ... should I write become or are`
55	Gail:	`they are`
56	Gro:	`and wait ... get children`
57	Gail:	`manage ... and survive`
58	Gro:	`and survive ... their children get`
59	Gail:	`get`
60	Gro:	`get the same opportunities` (predict population, group 5)

Excerpt 7

70	Eva:	`the development could have meant several things ... that the wolves got a better sense of smell ... or that the wolves who had a good sense of smell survived`
71	Emma:	`because they could find more animals and see enemies from long distances`
72	Eva:	`those wolves with, for example, a good sense of smell survived, 'cos they could sense the smell of prey` (predict population, group 3)

In excerpt 6, the students negotiated the importance of distinguishing between the words *are* and *become* (turn 54, `should I write become or are`), which relates to paying attention to the existing variation (`are`) in the population versus what this variation could lead to (`become`). Excerpt 7 makes the same aspect visible (turn 70, `the wolves got a better sense of smell ... or that the wolves who had a good sense of smell`), that is the difference between whether the wolves already *had* different abilities or if it was a result of selection (*got* better). In both excerpts, the students agree on a formulation that points to an explanation that draws on the existing variation. Furthermore, it is interesting that they, on the whole, stress the importance of the point. The existing variation was implicitly formulated in the information the students read, for example, potential difference in the length of legs of reindeers and the potential hunting success of wolves. Still, the students found it important to discuss the significance of this information as they formulated their own answers, answers that are neither in scientific nor colloquial language, but something in between, an interlanguage.

Linking and coherence when generating explanations

A main feature is that the generalised meaning of the term selection is only articulated if the existing variation is articulated or somehow taken for granted. In the computer-based activity, variation between populations is implied in the task, which the students discern, and in most of the discussions the term variation is taken as a point of departure. The students proceed rather directly with what the variation (difference) could lead to, thus articulating the meaning of selection.

The first excerpt in this section brings up all five components (individual variation, heredity, differential survival, differential reproduction, and accumulation) that Ferrari and Chi (1998) conclude should be part of an evolutionary explanation. However, it is done without explicit wording of the components.

Excerpt 8

110	Fia:	`those reindeers with longer legs could maybe run faster than those with short legs and then escape predators easier`
111	Fiona:	`lynxes ... lynxes`
112	Fia:	`lynxes and tigers and`
113	Fiona:	`wolves`
114	Fia:	`right wolves ... ok and then they survive and carry their genes on to their children who also get longer legs`
115	Fiona:	`yes`
116	Fia:	`and then they survive too and after many generations since it is a problem it turns out that many get longer legs`
117	Fiona:	`yes` (predict population, group 4)

The existing variation (some reindeers have longer legs) is taken as a point of departure and this variation has consequences when the reindeers are hunted; thus bringing the notion of *selection pressure* into the explanation; however, it is expressed in interlanguage: `since it is a problem it turns out`. One consequence is survival, a component of selection, `then they survive`. Heredity is rather weakly linked to the explanation of the origin of variation, but the term heredity is brought in with `carry their genes on to their children` (carry used as *transferred* sense of inheriting). This is also the part that points to the role of reproduction in the selection process. The component of accumulation is pointed out by mentioning that selection is repeated and takes many generations.

In the excerpts presented so far, the students mainly talk about natural selection, which was the intended focus in the teaching-learning sequence. However, when Fia and Fiona go on talking (see below), they raise another aspect of selection, sexual selection.

Excerpt 9

125	Fia:	`maybe they are also better looking`
126	Fiona:	`maybe they are ... write it down`
127	Fia:	`they are probably also sexier`
128	Fiona:	`please be more professional (`*`giggles`*`)`
129	Fia:	`(`*`writes`*`) more aesthetically pleasing` (predict population, group 4)

This discussion also points to the fact that the students seem aware of the existence of a certain way of expressing oneself in school science; thus pointing to the awareness of different social languages. The conversation about reindeers is first articulated in colloquial language, influenced by anthropomorphism. However, the colloquial words `better looking` and *`sexier`* are not assumed by the students themselves to be sufficiently correct. Furthermore, the words locally are situated exemplifications, which are in contrast to the more generalised expressions in school science. When submitting to the database, the words `better looking` and `sexier` are replaced by the synonymous `aesthetically pleasing`, – a sign of the students' view of the accepted formal school science language.

The last excerpt is an example of the generation of a causal explanation in the students' own choice of words. Furthermore, it is an example of how the students co-construct explanations.

Excerpt 10 (which is partly a fusion of excerpt 1 and 3)

84	Emma:	`I first thought that it was like mutations and that was surely true as well, but then it was also like this ... that those with longer legs survived better and then it was those who reproduced`
85	Eva:	`exactly, then we write like this ... let us take the example that all reindeers are chased by wolves ... the fastest survives`
86	Emma:	`which is the one with longest legs`
87	Eva:	`because it runs fastest, has a good mutation`
88	Emma:	`well`
89	Eva:	`first of all, it is a mutation that makes you get longer legs`
90	Emma:	`mm`
91	Eva:	`and since they would rather take your friend who doesn't have your mutation`
92	Emma:	`mm`
93	Eva:	`because they more easily get hold of your friend therefore you survive and your children get your dominant mutation` (predict population, group 3)

Emma mentions the aspect of heredity at the beginning (technical term `mutations`), and so does Eva both in the middle (technical term `mutations`), and at the end (`your children get your dominant mutation`). Variation is discerned (some had `longer legs`). This variation faces the environment (`all reindeers are chased by wolves`), thus resulting in selection (`the fastest survives`). When introducing the wolves in this example, the students touch upon the notion of *selection pressure*. The result of this pressure on the population of reindeers (hunting wolves) is formulated by Eva using interlanguage: `would rather take your friend who doesn't have your mutation /…/ more easily get hold of your friend therefore you survive.`

Discussion and implications

The students' reformulations of the key terms are made in an interlangue (Ash, 2008; Lemke, 1990) that borrows characteristics from two social languages: the colloquial and the school science languages. In this way, the students' talk is framed in a kind of hybrid language with translations between the different social languages and different interpretations of the terms are negotiated. The relations, and their significance for learning, between the use of single terms and these terms combined into coherent explanations such as the theory of evolution, are expressed by Lemke (1990) as: "the systems of related meanings that constitute a scientific theory are learned and used primarily through language and correspond to a thematic pattern of thematic items (key terms, or 'concept words') and their semantic relations to one and another" (p. 121). We will discuss two possible consequences of the students' different linguistic usage; first in relation to the quality of reasoning and then in relation to the students' learning.

The quality of the formulation and reformulation of terms is understood here in relation to the *meaning* of the term; what Vygotsky (1986) referred to as a word's collective, generalised, and lexical meaning. This is, in turn, connected to the learning goal in formal schooling, which, according to Vygotsky (1978): "is concerned with the assimilation of the fundamentals of scientific knowledge" (p. 84). As we have shown, the students express themselves in an interlanguage and the terms are contextualised with paralleling, delimiting and transferring strategies.

Taken individually, these contextualisation strategies tend to lack precision and often the quality is reduced and diluted in relation to the collective *meaning* of each term; for example, the term selection is delimited to one component: survival. However, looking at full explanations, the pattern is partly different; then the students are able to present rather coherent and scientifically sound explanations. For example, the students often include the necessary components of an evolutionary explanation (Ferrari & Chi, 1998) and they link these components in a coherent and causal manner. This conclusion is in line with Lemke's (1990) remark: "the meaning of the whole is more than the sum of the parts" (p. 12). This is most prevalent when students perform the population prediction activity, maybe due to the fact that the instructions on the screen explicitly pointed to the intraspecific variation (Wallin & Andersson, 2005). Likewise, in the selection game the intraspecific variation was also explicitly given, but in an oral form, although the students did not present coherent evolutionary explanations.

The students were part of a teaching intervention with the aim of focusing on the theory of evolution as a tool for reasoning, referring to specific terms. A rather promising evaluation of the students' learning outcome has been made elsewhere (Olander, 2009) based on an account of written answers three months after the teaching ended. For example, the students who participated in the intervention answered significantly more in line with a scientific view than a comparable national sample did. This development in reasoning could potentially be explained by the students' emerging use of interlanguge. Articulations in an interlanguage manner relate probably more to everyday experiences (than school science language) and might be easier to externalise in everyday situations and thus be elaborated and refined, even after and outside teaching in classrooms. Connecting school and everyday knowledge is epistemologically important when learning physics, according to Hammer and Elby (2003), and when learning biology (Brown & Ryoo, 2008; Ash, 2008).

Our choice of analysing students' talk when they participate in activities is inspired by the idea that no activity can speak for itself (Bergqvist, 1990), and the assumption that it is in the talk around the activities, not the activities as such, that learning can occur (Mortimer & Scott, 2003). However, the rationale when designing activities in pedagogical settings influences and frames the way the activities are received by the students. First, we will outline some differences between the use of *models* in science and school science and then discuss the rationale for the activities used in this study.

In science, models and modelling are used in order to describe and frame a specific part of the natural world; the purpose is mainly to make predictions and concordance with the natural world is the measure of quality. In school science, models and modelling are (delimited) versions of science, used mainly in order to describe and visualise scientific methods and the products of science. In the classroom, for example, methods and historically important experiments/detections could be demonstrated through laboratory work and concepts, models, and theories could be used as 'scripts' when designing student activities. The purpose is pedagogical, and clarity of explanation power is the measure of quality.

The activities focused on in this study, predict population and selection game, were framed as generalised descriptions (models) of the theory of evolution; which as scripts served a purpose in the school science version of the theory, referring to the terms variation, heredity, and selection. The similar features of the two activities were a focus on one typical trait (length of legs and colour, respectively) within a population, along with pointers towards change over time and generations. Both activities involved prey/predator as theme, however, in the selection game prey/predator (paper clips and students) were part of the initial rules. In contrast, in the predict population activity the prey-aspect was introduced first and predators later on (however, many students referred to predators almost immediately). Nevertheless, the aspiration with modelling, whether it concerns scientific prediction or pedagogical clarity, is the possibility of making connections to 'the world'. The findings of this study are that there are rather few occasions when the students connect the actual activity with the world outside.

What are the implications of the fact that the students do not verbally articulate the key terms? After all, we have shown that the terms have specific meanings and enhance comprehensible communication, at least when used inside the scientific community. From a school science perspective, the reformulations *decrease the precision* momentarily, but not necessarily in the long run, because it is part of the process of sense-making. It could cause problems for those students who choose science for further study and a career. However, if they have grasped the *meaning* of the terms it would be fairly easy to 'copy' the accurate terms for the phenomena; the meaning of the term in that specific scientific community (cf. Brown & Ryoo, 2008). The reformulations *increase the relevance*, in the sense that the verbalisation of an explanation in an interlanguage is advantageous when communicating in social life outside the science classroom and thus the possibility of further sense-making is enhanced; an ongoing sense-making process that Hammer and Elby (2003) describe as "reconstructing and refining one's current understanding" (p.54). Moreover, being comprehensible without flawing the scientific meaning is a rare ability – perhaps interlanguage is the key.

Notes

1. Aposematism is (a defence mechanism) when an organism has a colour that resembles a poisonous species, for example, the poison dart frog (*Dendrobates tinctorius*), which probably is the frog that Anna is referring to.

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