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Collaborative processes in species identification using an internet-based taxonomic resource

Jani Kontkanen[a], Sirpa Kärkkäinen[a], Patrick Dillon[a], Anu Hartikainen-Ahia[a] and Mauri Åhlberg[b]

[a]School of Applied Educational Science and Teacher Education, Philosophical Faculty, University of Eastern Finland, Joensuu, Finland; [b]Department of Teacher Education, University of Helsinki, Helsinki, Finland

ABSTRACT
Visual databases are increasingly important resources through which individuals and groups can undertake species identification. This paper reports research on the collaborative processes undertaken by pre-service teacher students when working in small groups to identify birds using an Internet-based taxonomic resource. The student groups are conceptualised as 'knowledge-building communities' working in a 'joint problem space' comprising the collective knowledge of the participants interacting with the taxonomic database. Collaborative group work and associated dialogue were recorded with digital video. The recordings were analysed for the categories of dialogue and the categories of knowledge used by the students as they interacted with the taxonomic database and how they drew on their previous experiences of identifying birds. The outcomes are discussed in the context of the interplay of individual and social processes and the interplay between abstraction and lived experience in the joint problem space.

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Introduction

Species are the basic building blocks of biological research, teaching and learning. According to Mayr (2004) without knowledge of species, biological knowledge is practically meaningless. However, modern biology curricula focus on aspects of genetics, ecology and evolution, and there is less coverage of systematics than in earlier times. Randler (2008) argues that the ability to identify species is important not only for understanding these branches of biology but also for a better understanding of biodiversity and issues about the environment and sustainability. Professional ecologists (e.g. Gotelli, 2004) claim that we need 'well written taxonomic keys based (where possible) on morphological characters for species-level identifications'. Gotelli (pp. 587–588) continues: 'The keys should give good details on known geographical ranges, habitat associations, and also contain information on distinguishing easily confused species.' Gotelli's preference is for dichotomous keys, but he acknowledges that they may not be necessary or desirable

CONTACT Jani Kontkanen jani.kontkanen@uef.fi

for some taxonomic groups. Existing keys and field guides for birds, he says, should be used as a 'gold standard' for what is possible in a well-written and useful key.

Whereas plants can be examined at close quarters, and therefore attention in identification can be given to the detail of morphological features through a dichotomous key, birds are typically identified in the field where visual characteristics, especially appearance and behaviour, are important in distinguishing one species from another. Visual characteristics include the bird's overall size and shape; the sizes and shapes of its bill (beak); legs, wings and tail; colours and markings generally and on specific parts of the body; and types of movement, flight and display. These are the characteristics on which field guides and manuals are typically based (e.g. Mullarney, Svensson, Zetterström, & Grant, 1999). Field guides generally contain information about geographical range and habitat, which can be used for second-level corroboration.

Generally, students are able to identify species at the higher taxonomic levels – family, or order for example, but not at the species level (Randler, 2006), that is, at basic visual levels rather than subordinate visual levels (Tanaka & Taylor, 1991). Databases of visual images held on computers or available through the Internet can be used to help students explore distinguishing characteristics and move systematically from basic to more subordinate levels of identification (Sharples, 1991). In a computer-aided presentation and memorisation exercise, Randler and Metz (2005) found that students better retained names and characteristics if they had visual associations.

Computer/Internet-based visual databases are increasingly important resources through which both individuals and groups can undertake species identification. Although collaboration in computer-mediated environments has been widely studied (e.g. Clark et al., 1996; Dillenbourg, Järvelä, & Fischer, 2009; Stahl, Koschmann, & Suthers, 2006), very little has been published on the processes undertaken by groups of individuals working collectively with taxonomic resources in species identification.

The purpose of this research was to investigate the *collaborative processes and forms of knowledge* undertaken by pre-service teacher students when working in small groups to identify birds using an Internet-based taxonomic resource. The research questions were:

When using the resource for species identification, how do the groups:

(i) utilise collaborative dialogue, and
(ii) apply different forms of knowledge

The student groups were conceptualised as 'knowledge-building communities' working in a 'joint problem space' comprising the collective knowledge and experience of the participants interacting with the taxonomic database. The research can be set in the wider context of inquiry-based science instruction and learning. Minner, Levy, and Century (2010), in a review of research for the years 1984–2002, found that inquiry-based instruction in science has a positive impact on content learning. The amount of inquiry, especially hands-on engagement with science phenomena and students taking responsibility for their own learning, were significant predictors of better learning.

Theoretical framing

Collaboration has been defined by Roschelle and Teasley (1995) as 'a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem' (p. 70). Central to this idea of collaboration is the 'joint problem space', a shared knowledge structure that integrates goals, descriptions of the current state of the problem-solving activity, available problem-solving actions and ways to promote shared actions towards the shared goals. In the research reported here, the joint problem space comprised the participants, the Internet-based taxonomic resource NatureGate together with an educational task, and the context in which the task was undertaken.

Scardamalia and Bereiter (2006) report an increase in collective knowledge when small groups of students are supported with computer-based resources. Stahl (2006) attributes this to the collective resource encompassed in the prior experiences and knowledge of the group members and the ways in which they collaboratively utilise artefacts in the learning environment: 'The knowing that groups build up in manifold forms is what becomes internalized by their members as individual learning and externalized in their communities as certifiable knowledge' (p.16). According to Sarmiento and Stahl (2008), social meaning is produced through a process of collective agreement when people communicate in a joint problem space. The joint problem space is not the property of any one individual; rather it is an activity that is socially constructed during knowledge-building. The creation, referencing, manipulation, assessment and re-use of knowledge artefacts in the joint problem space serve as bridging activities between participants during collaborative knowledge-building.

Learning within a joint problem space offers students opportunities to negotiate common understandings about the task and benefit from the multiple viewpoints of their peers; this is one of number of 'attributes of meaningful learning' as specified by Jonassen, Peck, and Wilson (1999). Inquiry and reflection are central to negotiated understanding and social meaning-making. Reflection processes are critical parts of inquiry and essential to process management and sense-making. Inquiry involves constructing and articulating arguments, reviewing and reflecting on them, synthesising explanations of results and recognising weaknesses and strengths in one's own thinking and within the investigation process (Quintana et al., 2004).

In the research reported here, processes of inquiring and reflection are investigated through the incidence of different forms of collaborative dialogue—recall, discussion, demonstration, comparison, analysis, assertion, argument and synthesis—utilised by the students whilst on task. Walton's (1998, p. 29) definition of dialogue as 'conventionalised, purposive joint activity between two [or more] speech partners' was taken by the researchers as a basis for the specification of the categories of dialogue. As Walton observers, this abstract definition of dialogue may be applied to different types of 'joint activities' by means of dialogue types related to the nature of the interaction. The researchers, two of whom are biology lecturers, thus pre-specified the categories of dialogue based on their experiences of the conventions of species identification. The categories of collaborative dialogue are defined in Table 1.

Collaborative knowledge-building and social meaning-making were evidenced through the students' processes of inquiry and reflection in the construction and application of biological, ecological, environmental and conservation knowledge as they interacted with the taxonomic database and negotiated with each other. Like the categories of dialogue, these categories of knowledge were pre-specified by the researchers based on their experiences and expectations of how knowledge is applied in species identification. These categories of knowledge are defined in Table 2.

Table 1. Categories of dialogue used in species identification.

Category	Description
Recall	Recovering detail of original circumstances (e.g. when photo was taken).
Discussion	Conversation concerning particular topic, that is, a *focused* conversation (i.e. when they are 'on task').
Comparison	Discussion focused on similarities and differences.
Demonstration	Using some bodily activity to illustrate a characteristic (e.g. span between hands to show size).
Analysis	Breaking the discussion of characteristics into smaller parts to gain a better understanding.
Assertion	A statement of belief that something is true.
Argument	An attempt to persuade someone that something is true.
Synthesis	[At end of process] combination of two or more entities (ideas/characteristics) to reach a conclusion.

Table 2. Categories of knowledge used in species identification.

Category	Description
Biological detail	Use of biological terminology that is additional to, or goes beyond, the terms used in the NatureGate characteristics. (e.g. beak, tail, wing are all used by NatureGate so these do not count as biological detail. But, for example, mandible, tarsus, secondary or primary feathers are not used in NatureGate and so would count as biological detail).
Ecological detail	Any comment: (i) to do with the ecology of the bird, for example, statements about its habitat; (ii) about its behaviour that is not listed in the NatureGate characteristics; (iii) about the status or distribution of the bird; (iv) about what it eats or predation.
Conservation or environmental management	Any comment about any aspect of conservation, for example, if a bird is declining, or is hunted, or is protected.
How they drew on previous experience of bird identification	This is not the same as recall; it is when somebody remembers seeing the bird or a similar one and recounts the experience or some detail from it. In other words, some experience of the bird before the NatureGate exercise.
Critique of the way NatureGate works	Not just complaints, but comments that show difficulties in understanding/interpretation or working through the process.
Passion for subject matter	Any examples of where someone is really excited about the identification or where he or she has a 'passionate' interest in birds.
Others?	There may be other dialogue content that I have not thought of. If anything interesting is said please record it!

Whereas the joint problem space is a useful general framework for investigating collaborative learning, recent research has extended our understanding of the dynamics of collaboration. In this paper we extend the notion of a joint problem space to include considerations of the interplay between individual and social processes (Järvelä, Volet, & Jarvenojä, 2010) and the interplay between abstraction and lived experience (Dillon, Wang, Vesisenaho, Valtonen, & Havu-Nuutinen, 2013).

Method

The research was conducted with teacher students studying multidisciplinary studies in basic education at the University of Eastern Finland. 'Multidisciplinary studies' means a total of 60 credit points for studies that all teacher students specialising in class teaching take from different subjects: mathematics, Finnish language and literature, sports education, arts, crafts, music, combined biology & geography, combined physics & chemistry, combined history & civics and religion. They can also choose two elective extra courses from the subjects listed above. The data for this research were collected during the students' biology course. Students worked in small groups collaboratively identifying birds using the NatureGate online resource (www.naturegate.net). NatureGate is a free, open-access, interactive resource structured around a photographic database that supports identification of plants and animals. Pilot research with NatureGate has focused mainly on the identification of plants (Åhlberg et al., 2014). The research reported here concerns collaborative processes in the identification of birds.

A mixed method approach was used in this research using: (i) theory-driven content analysis (Miles & Huberman, 1994; Savenye & Robinson, 2005) to establish categories of dialogue and the forms of knowledge used in the dialogue; (ii) diagrammatic representations as 'operational flowcharts' (Figures 2 and 4) of the sequence of decisions taken with the taxonomic database relative to the dialogue; and (iii) quantitative tabulations of the categories of dialogue and forms of knowledge used in the dialogue. All dialogue associated with a given identification was video recorded. Data compression to derive incidence of categories from the dialogue was undertaken qualitatively by two researchers independently viewing the videos and scoring the categories. The two researchers compared and discussed their scorings until consensus was reached.

The main observation categories (characteristics) for bird identification in NatureGate are given in Table 3. Each of these main categories is divided into sub-categories (second-level)—for example, for main colour, there are nine sub-categories of different colour. These are further sub-categorised (third-level).

Students (68) worked in 18 groups of 2–6, the optimum size for working together with a shared computer resource. The students were allowed to choose their group size and membership. Students were asked to photograph a bird 'in the field', that is, out of the laboratory setting in which they were working with the taxonomic database. Back in the laboratory, they worked together in identifying the bird using NatureGate. They were asked to talk aloud as they carried out the identification. The task was undertaken in spring, the best time in Finland for field work on birds as they are migrating back after winter.

In NatureGate, identification starts by a user selecting one of the four main categories. A set of related second-level symbols appear beneath that category. Clicking one of these reveals a set of third-level symbols. Activating one of these symbols by clicking on it

Table 3. The main observation categories for bird identification in NatureGate.

Category	Sub-categories
Date and location (nesting habitat)	Time of observation
	Nesting habitat
Colouring and markings	Main colour
	Colouring of distinctive body parts
	Distinctive markings
	Head
	Upper parts
	Lower parts
	Wings
	Tail
	Eye colour
	Beak
	Legs
Shape and size	Size
	Wings
	Legs
	Beak
	Crest
	Long neck
	Long tail
Behaviour	On the ground
	In water
	In flight
	Entering a hole or nest-box
	Climbing a tree trunk
	On a bird table
	Catching insects in flight
	Sounds

reveals images of birds that have these characteristics. Users may click on two or more third-level symbols if they are not sure which alternative corresponds best to their observation.

Collaborative group work and associated dialogue were recorded with a digital video camera, which was placed behind the students in such a way that the students' actions, the original photographs they were using, and their interactions with NatureGate and with each other were shown. NatureGate was also projected to a whiteboard to make it easier for the groups to collectively define the selections they made during the process of identification. The researcher set up the camera and observed the student groups. The researcher stayed at the back of the room and was on-hand to deal with any technical difficulty but did not interfere with the process of identification or influence the groups working on task. Before the students began working with the task, the researcher explained to them what was expected: identifying the bird they had photographed, talking aloud about what they were thinking and doing during the process and briefly describing how they were using NatureGate. There are 18 recordings; each one shows a whole group's work of 1–3 birds being identified.

The recordings were analysed in three stages

First, sequences of menu choices leading to the identification of the bird were recorded as operational flowcharts showing the selections made in NatureGate and the dialogue associated with each selection. Each choice from the NatureGate menu involves adding or removing a characteristic. Each choice and transition is shown on the flowchart as an arrow. Arrows demonstrating the choices return to the box they leave from. The characteristics added during identification are shown in the flowcharts above the box and characteristics removed are shown below the box. Transitions have thicker arrows and go from one box to another. All arrows are numbered, showing the order of the steps undertaken by the groups during the identification process.

All 18 recordings were viewed by two researchers who analysed them using theory-driven content analysis, that is, against the categories as defined in Table 1. The two researchers simultaneously made individual notes of the dialogue and wrote down the occurrences of the categories. After viewing each recording, the researchers discussed and compared their notes and wrote down a synthesis of their analyses.

Next, seven cases from the recordings were purposefully selected to represent a range of different identification scenarios (e.g. group size; long/short identification process; different species of birds; one person dominant/no person dominant) for the second stage of analysis. The purposeful selection was to get a representative cross selection of the cases, not to make comparative analysis of different group factors. The recordings were viewed a second time relative to the operational flowcharts and the charts were revised where necessary. After revising the flowcharts, three researchers watched the recordings again, this time using theory-driven content analysis looking for incidences of the knowledge categories as defined in Table 2. The researchers also looked for additional categories that emerged from the data, that is, categories that were not pre-defined. As in the previous stage, the researchers made notes of the details of the incidences; they also refined their notes on incidences of the categories looked at in stage 1. The researchers then discussed together the recordings and their observations and notes to reach consensus about the incidence of categories and then made a synthesis of their analyses.

Data from the first two stages were consolidated to find generalised patterns. These generalised patterns provided an insight into the relationship between how the groups performed the task (identifying a species) and the collective understanding they had about the processes involved in the task (the way they explained how they made the identification).

One of the researchers was in the laboratory when the recordings of the tasks were made and the other two researchers were also teachers of the course. After all the stages of the analysis had been completed, the researchers met to discuss the outcomes and take an overview of them. Some of the general observations arising from this overview are given in the discussion below.

Results

Recordings, transcriptions and analyses were made of the work of seven groups, each group working together on identifying a bird. Table 4 gives the composition of the seven groups (numbers of males and females), the identity of the bird, the length of time (minutes and seconds) it took for the group to arrive at a suggested identity for the bird, and the incidence of categories of dialogue involved in the identification. Although all groups arrived at identification, not all of the identifications were correct. Analysis of the dialogue revealed that 'discussion' cannot meaningfully be quantified as a discrete category since it is associated with all other forms of dialogue and thus may be regarded as a 'meta-category'. The frequency of categories of dialogue is in the following order of magnitude: [Discussion]>analysis>assertion>comparison>recall>argument>demonstration>synthesis.

Table 4. Frequencies of categories of dialogue in stage I of analysis.

Group details				Categories: Stage I							
Case #	Genders	Bird	Length	Recall	Discussion[a]	Comparison	Demonstration	Analysis	Assertion	Argument	Synthesis
1	3F&1M	Snow bunting	6:45		N/A	2		5	1		
2	3M	Pheasant	7:30		N/A	1		6	1	1	1
3	4F	[stuffed] Owl[b]	5:30	1	N/A		3	3	1	2	
4	6F	Goldeneye	11:45	3	N/A	4		5	3	2	
5	3F&1M	Jackdaw	3:30	1	N/A	1		2	3	1	
6	2F	Yellowhammer	7:00	4	N/A	3	1	5	5	3	1
7	3F	Fieldfare	14:00	3	N/A	3		5	3	2	
Total: 26 Participants				12	N/A	14	4	31	17	11	2

[a]Discussion cannot be meaningfully quantified as it was present with all other forms of dialogue.
[b]The students were set the task of taking a photograph of a bird 'in the field' which was taken by them to mean 'outside the laboratory'. We did not specify that they should photograph a live bird but we assumed that they would, and indeed all but one group did. We have included this case of the stuffed owl in our analysis because of the collaborative processes it demonstrates. We accept that it does not represent good practice in field biology.

Table 5. Frequencies of knowledge and experience themes found in stage II of analysis.

Group details				Categories: Stage II							
Case #	Genders	Bird	Length	Biological	Ecological	Male/Female[a]	Previous exp.[b]	Passion	NG[c] critique	Photo critique	Self-doubt
1	3F&1M	Snow bunting	6:45	3		1			2	1	3
2	3M	Pheasant	7:30			1	1		2	2	1
3	4F	[stuffed] Owl	5:30	4	1		5	1	3	1	2
4	6F	Goldeneye	11:45	9	4	1	2	2	11	2	8
5	3F&1M	Jackdaw	3:30		1					1	
6	2F	Yellowhammer	7:00	3	1	2	4	4	2	4	3
7	3F	Fieldfare	14:00	3	3		2		2	1	3
Total: 26 Participants				22	10	5	14	7	22	12	20

[a]Stands for a situation where the students discussed differences between genders and/or their relation to the photo in NatureGate.
[b]Previous experience includes clearly expressed prior knowledge of the bird being identified.
[c]NatureGate.

Table 5 gives the frequencies of different categories of knowledge content in the dialogue for each of the seven groups. Taken together, the categories concerned with critique (of the NatureGate resource and the groups own photographs) were most frequent. 'Self-doubt' was not a category we expected to find prior to the investigation but it emerged from the data as one of the dominate forms of dialogue content. The analysis revealed more biological knowledge than ecological knowledge. There was no evidence of knowledge of conservation or environmental management (although strictly speaking the task was not set up for this). There was use of previous experience. 'Passion' for the subject matter was not evident in the dialogue content.

To show how the whole analysis was undertaken, two illustrative cases are given

The flowcharts used in the cases below were created by hand for all seven groups that were part of the analysis. Drafts of the flowcharts were drawn based on the identification processes undertaken by each group, that is, the categories of dialogue they used during their identifications and the choices they made while using Nature Gate during the identifications. The flowcharts were then further refined and put into electronic format using Microsoft Word. To read and follow the flowcharts, the following points are important:

(1) The identification processes run left to right.
(2) The identification processes follow a numerical order from 1 to whichever number is highest in the flowchart in question. These steps are in separate black boxes with white fonts stating the number of the step.
(3) The boxes running through the middle of the flowcharts that are divided into two sections show, in the lower section, the categories and sub-categories of NatureGate used in the identification and, in the upper section, the categories of dialogue used. All arrows begin from the right edge of these boxes.
(4) Arrows that are drawn *above the box* (i.e. those that begin from the box and end in the box, turning only left) are steps where the group *added* a selection in that category.
(5) Arrows that are drawn *below the box* (i.e. those that begin from the box and end in the box, turning only right) are steps where the group *removed* a selection in that category.
(6) Inside the arrows (points 4 and 5), the selections are listed in the boxes. The headline in each box states either 'added' or 'removed' to clarify the action in question. Below the headline, the left statement shows *the detail* and right statement shows *the selection*.
(7) Each box mentioned in point 6 relates to the arrows *surrounding* it. Arrows and boxes are in order so that the first steps are closest to the central boxes with the two sections and later steps are successively further away, above or below the boxes.
(8) Arrows that do not begin from and end in the same box are transitions between categories or sub-categories used in NatureGate (i.e. the group changes the category of characteristic to progress with the identification of the bird).

Case 1

This was a group of three female students and one male. Their photograph (Figure 1, left side) was of a snow bunting. The corresponding NatureGate image is given in the right

Figure 1. Student (left) and NatureGate (right) images for snow bunting.

side of Figure 1. The group spent 6.45 minutes on the identification task before giving up. During the task they expressed a lot of self-doubt and were critical of both their own image and the NatureGate database. They used biological terminology in their dialogue.

Summary analysis of digital recording: The group worked quite actively. One student seemed uninterested in NatureGate and was most of the time in the background. One student was majoring in biology and she guided the group through the process of identification. She claimed to know the bird from the onset and her dominant behaviour had a somewhat negative effect on the motivation of the rest of the group. Two of the students seemed bored at times, but they tried to stay focused and interested and commented from time to time. They made little progress with NatureGate so the biology student gave them specific instructions for interrogating the database, based on her assumptions and prior knowledge rather than the features shown on the photograph they were using. This resulted in them not finding the bird. The flowchart of the operations of this group is given in Figure 2.

Explanation of the flowchart and how it relates to the main dialogue: The group began with a discussion of the bird's colouring [steps 1–5 in flowchart above]. They also tried to find specific markings ('And the wing tips are black, is there that kind of a place […]') but they could not be found in NatureGate. After selecting some specific markings from NatureGate, the student who thought she knew the bird stated that the bird is not in their list of possible birds ('Now it has gone […] It is none of these […] Something has like gone wrong'.) so they continued by removing some selections [steps 6 and 7]. They moved on to discuss the size of the bird [step 8] at which point the dominant student stated that she knew that 'the bird is smaller than some seagull', which guided the group's selections [steps 9 and 10]. After choosing the size for the bird, they thought there was something wrong with the colours ('*main colour might not be white?*') [step 11] and they removed both their selections for main colour [steps 12 and 13]. They still did not find their bird and they discussed the gender of the bird ('That can be the female and then those others males'.) and other errors relating to colouring and markings they had made during their identification. After their discussion, they gave up [step 14] and started again from the beginning.

Case 2

This was a group of three male students. Their photograph (Figure 3, left side) was of a pheasant. The corresponding NatureGate image is given in the right side of Figure 3.

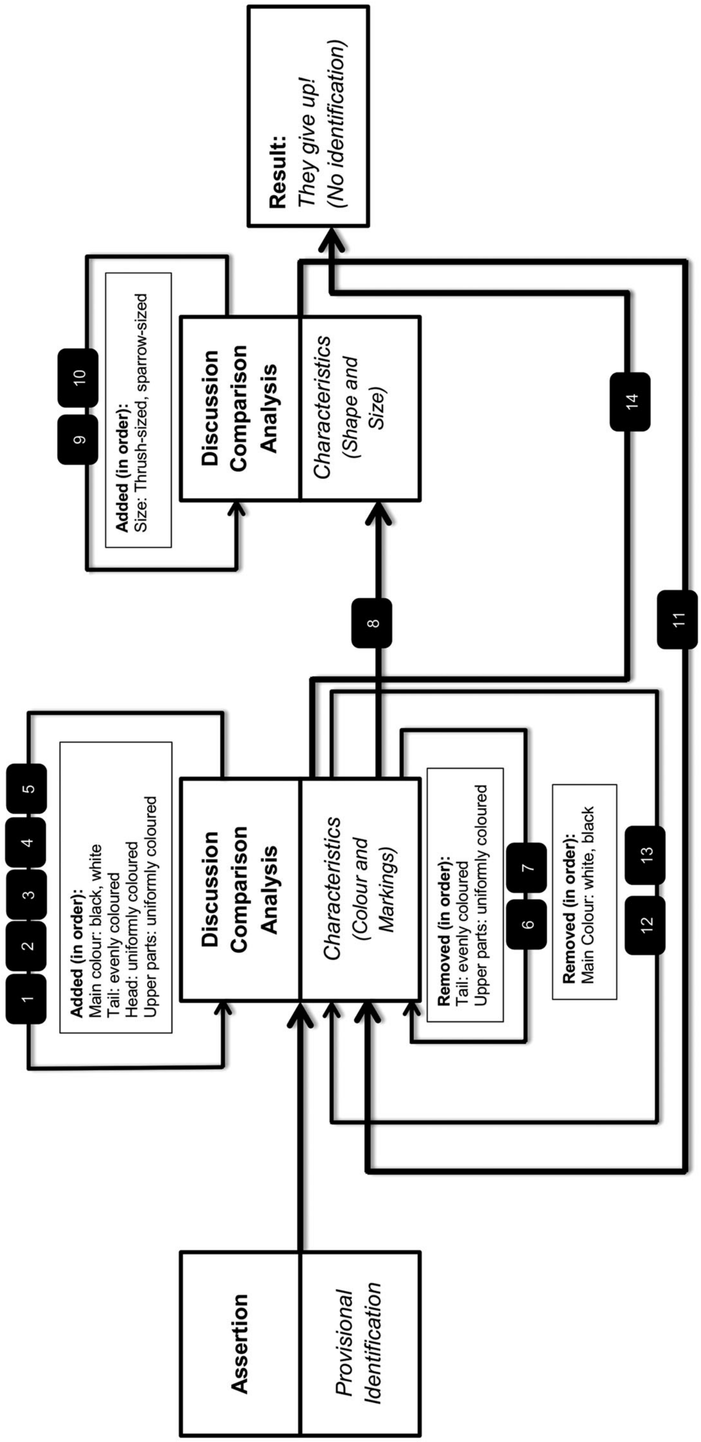

Figure 2. Operational flowchart for Case 1.

Figure 3. Student (left) and NatureGate (right) images for pheasant.

The group arrived at the correct identification after 7.30 minutes. During the task they expressed some self-doubt and were critical of both their own image and the NatureGate database. They did not use specialist terminology in their dialogue but they did draw on previous experiences.

Summary analysis of digital recording: One of the students took the photograph on his cell phone. They all studied the photograph before beginning to use NatureGate. The student who took the photograph gave guidance about what to select in NatureGate but they collectively discussed the possible choices and the features available on NatureGate. They paid attention to different details of the bird and made corresponding choices in NatureGate. One student was in the background, but he seemed to know what the bird was: 'choose option X' he said, and the option was chosen by the student using the computer. It was the correct bird. The flowchart of the operations of this group is given in Figure 4.

Explanation of the flowchart and how it relates to the main dialogue: The group begun their task by looking at a photograph in one student's cellphone screen noting the date when it was taken ('Let's begin; this has been taken in the summer'.). They looked at possible choices from the 'date and location/ time of observation menu' in NatureGate and selected 'late spring-early summer' [step 1] after the student who had taken the photograph stated that '[…] It has been taken in the beginning of June'. They moved on to 'colouring and markings' [step 2] and discussed the colours of the bird. They all agreed on the main colour [step 3]. Next they tried to see if they could select 'head colour' ('head is some dark colour') but selected 'uniformly coloured' [step 4] as there is no selection for head colour in NatureGate. One of the students wanted to move on to size ('Then I guess, size?'), but the student in control of the database wanted to stay in 'colourings' and select something relating to the tail, so the group selected 'tail: evenly coloured' [step 5]. At this point they had 17 possible birds left and could have made a correct identification from the images available, but they continued to work through the database, reducing the number of birds and discussing bird behaviour [step 6]. They agreed unanimously that the bird walks on the ground (student 3: 'Walks, hops, or, well'. student 1: 'Walks'. student 2: 'Walks') [step 7]. Now they noticed that the bird was not in the list of possibilities (student 3:'here are really, we didn't get even close' student 1: 'that's not correct now' student 2: 'what goes wrong in it now?') and decided to go back to 'colouring and markings' [step 8] and remove 'head colouring' [step 9]. They also considered removing the

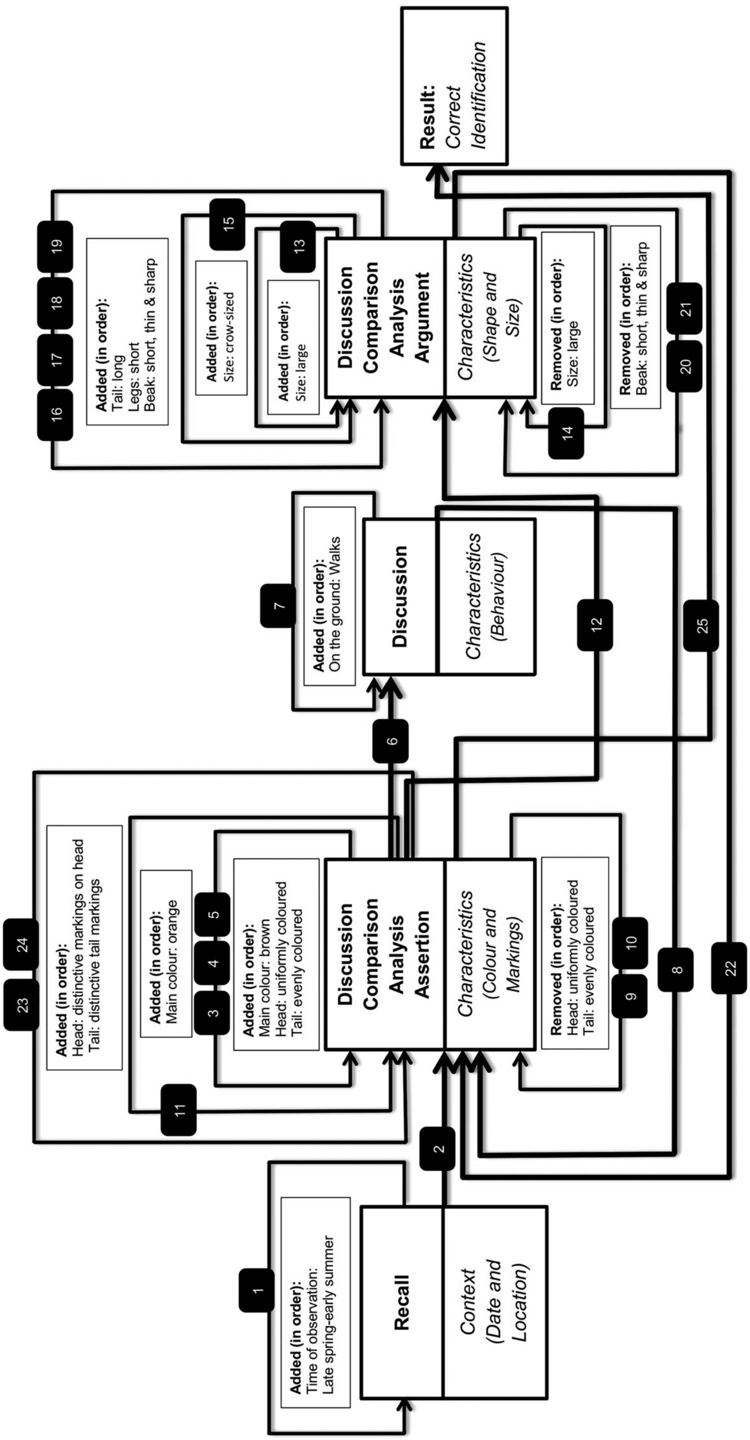

Figure 4. Operational flowchart for Case 2.

main colour, but one student stated the bird was in the list after they selected the main colour earlier ('[…] It [bird] was still in there when it still was [main colour: brown]'.). They removed 'tail colouring' instead [step 10]. They also tested if two main colours can be chosen from NatureGate [step 11]. They moved on to 'shape and size' [step 12] after the student who wanted to go to size earlier stated 'Let's take that size, it drops out quite many of those little birds'. After discussing the possible selections for size they choose 'large' as their size [step 13] but NatureGate gave them no possible birds and it seemed to freeze so they removed their selection [step 14] to make it work again and choose 'crow-sized' instead [step 15]. They moved on to select different body parts [steps 16–19], agreeing with each others' decisions. The example pictures offered in NatureGate gave them trouble and they stated 'This beak is difficult really'., so they removed the beak entirely [steps 20 and 21]. They looked at other possibilities in the 'shape and size' menu, but they did not reach a conclusion. Instead, they went back to 'colouring and markings' [step 22] and choose 'distinctive marking's [steps 23 and 24] on both head ('well head is different coloured, that is a very certain thing […]') and tail ('[…] the tail looks a bit multi-coloured, isn't it striped or multi-coloured? Let's see what happens'.) partly deduced from their previous selections that were incorrect. Now they had only four birds left and they reached the correct identification [step 24]; they even discussed differences between different genders of the bird ('[…] look, female is the same colour, but […] male's head is that kind of, and there is that light-coloured stripe visible that is shown there also'.).

Discussion

Collaborative knowledge-building and social meaning-making were evidenced through the students' processes of inquiry and reflection in both the identification of species and the construction and application of biological, ecological, environmental and conservation knowledge as they interacted with the taxonomic database and discussed and negotiated with each other.

In reviewing literature on species identification, Randler (2008) found claims that many syllabi emphasise or require the use of scientific keys for identification, the argument being that they help students look more closely at detail (and are more scientifically precise). In contrast, when using books, students tend to focus on the illustrations alone (and the evidence from the study reported here suggests that the same is true of Internet-based visual resources, indeed some students compared NatureGate with working through pictures in a book). In testing these claims, Randler (2008) found that students performed better when using a picture-based identification key. There is thus a tension between the use of scientific keys which may develop better understanding of biological detail and yield more precise outcomes and the use of visual resources which are easier to use but which may not lead to such deep learning. In this task, using an online database for identification did not necessarily lead to successful identification (in fact most groups did not make a correct identification) but this was in large part due to the poor quality of the students' photographs. The quality of the photographic resources that the student teachers brought to the task was an important learning point for them, and it also emphasised the difficulty of getting close enough to birds in the field to identify them, with or without the help of a camera and database.

The operational flowcharts for identification show the following operations: selecting the distinctive features of the bird (e.g. size, colouration – the 'variables'); working systematically with the variables: drawing on prior knowledge; making comparisons; looking for similarities and differences; eliminating some variables; taking more promising variables to the next stage of identification. The flowcharts illustrate the importance of circularity in adding and subtracting variables, literally cycling through the database. This contrasts with the more linear process of systematically working through a dichotomous key. In a study of computer-supported collaborative learning, Krange, Fjuk, Larsen, and Ludvigsen (2002) identified both sequentially and dynamically oriented activities. In the first, students performed the actions one after the other with little reflection on the specific character of the learning environment they were a part of. In the second, when the students tried something out, they returned to those actions and reflected on them. The study reported here conforms to the second case: the cyclic nature of the processes of identification encouraged by the database (as shown in the operational flowcharts) promoted students to reflect on the affordances offered by the learning environment (i.e. properties of the environment relating to its potential utility). This is illustrated very clearly in case 2 above, which shows how deeply engaged the students were, going beyond the task specification of identifying the bird and exploring the limits of the database.

The operational flowcharts and the associated commentaries also show critical points in the identification – breakthroughs, major ambiguities, failure to reach consensus – and how they were resolved. Resolution of difficulties typically came through one individual making an assertion based on prior experiences or invoking more specialised knowledge (e.g. of bird behaviour as in case 1, decision point 6) and thus directing the next stage in the process. These critical points can be likened to improvisations: they typically involve nonlinear and non-standard thinking, or developing new associations between existing ideas or concepts, or the exploration and generation of new ideas (Dillon et al., 2013). In contrast to critical points, the commentaries accompanying the flowcharts also reveal many instances of students being critical of their own photographs and/or of aspects of the database leading to self-doubt and reduced confidence.

Even discounting the data from the case of the stuffed owl, where there was less scope for demonstrating ecological knowledge, the students used more biological knowledge (evidenced through use of anatomical and physiological terminology) than ecological knowledge (evidenced through statements about habitat, distribution, status and behaviour) in the processes of identification. This is surprising since Boys (2004) found that watching natural history programmes on television can increase an individual's ecological knowledge as can the amount of time the individual spends in countryside recreation. There is considerable television coverage of natural history in Finland and countryside recreation is a strong element in Finnish culture. Although neither of these factors was investigated as a background to the research reported here, they may nevertheless be significant contextually since Birchenough (2002) showed that different social groups in Britain differed in their environmental knowledge: those whose livelihood or hobby (e.g. fishing) brought them into contact with wildlife had good environmental knowledge. The knowledge of other social groups was poor, probably aligning with what Louv (2010) has called 'nature deficit' to account for the lack of direct experience of the natural world characterising many of today's young people.

Moreover study material was taken from 'the field' (i.e. most students went into the countryside to take their photographs of birds). The dominance of biological over ecological knowledge may reflect the strong tradition in Finland of lecture-room and laboratory-based biological education (see e.g. Palmberg, 2012; Palmberg & Kuru, 2000). However, the Finnish national core curricula for basic education (Finnish National Board of Education, 2004a, pp. 170–181) and for upper secondary schools (Finnish National Board of Education, 2004b, pp. 134–139) emphasise learning environmental and nature studies, and biology in outdoor environments as well as in the laboratory or through lectures. The dominance of biological over ecological knowledge may also reflect the number of winter months during the school year; the months during which the amount of plants and birds are few (due to snow cover and migration).

Although the task was not set up specifically to show the application of knowledge of conservation and environmental management, there was no evidence of either form of knowledge. Again, this is surprising given the assumed high level of environmental awareness in Finland (see e.g. Palmberg & Kuru, 2000; Yli-Panula & Matikainen, 2014) and it has implications for education for sustainable development which requires applied knowledge including that of species identification. Randler and Bogner (2006) found that hands-on group work is significantly better than a teacher-centred presentation for species identification. Randler and Bogner (2006) also suggest that for some species teaching about identification should be embedded in learning about their natural histories and life histories so that students can see the connections. Teaching species names simply as labelling they say is detrimental.

In the research reported here, collaboration took the form of coordinated, synchronous activity (collective use of an Internet-based taxonomic resource) in a joint problem space in an attempt to construct and maintain a shared conception of a problem (identifying species of birds). The processes of collaboration were investigated through categories of dialogue. Analysis of dialogue showed the flowing hierarchy of discussion categories: analysis>assertion>comparison>recall>argument>demonstration>synthesis.

Analysis and comparison were central forms of dialogue in cycling through the database, adding and subtracting variables. The operational flowcharts show argument and demonstration to be important in processes of clarification and in some cases (along with assertion) for moving on from a critical point. There were only two incidences of synthesis. Possible explanations for the low incidence of synthesis are: (i) it occurs less frequently because it is a higher level skill; (ii) it is less likely to occur in collaborative rather than individual situations because of the social dynamics of groups; or (iii) the goal-directed nature of the task concentrates effort on outcome rather than understanding how the outcome is arrived at.

This research offers a more nuanced insight into the notion of 'a joint problem space' (Roschelle & Teasley, 1995) through some recent perspectives from educational psychology (the interplay of individual and social processes, Järvelä et al., 2010) and cultural ecology (the interplay between abstraction and lived experience, Dillon et al., 2013).

Järvelä et al. (2010) argue for looking at motivation in collaborative learning as the interplay between individual and social processes. Järvelä et al. (2010) cite Nolen and Ward's (2008) claim that motivation is: (i) *socially influenced* by the context, and (ii) *socially constructed* through interactions where individuals and context are inseparable and mutually constitutive. Järvelä et al. (2010) develop this argument into the interplay between: (i) a cognitive angle, where individual group members are seen as interdependent self-regulating agents, and (ii) a situative angle, where individual group members constitute a social entity that creates affordances for and constraints on engagement in the activity. The subtle interplay between individual and collective dynamics in processes of collaboration was seen in the research reported here, most noticeably in case 1, where a student majoring in biology had a dominant, but in terms of the task, erroneous, influence on the group.

The perspective of Järvelä et al. (2010) from educational psychology is broadly compatible with conceptualising collaborative learning as a 'cultural ecology'. Cultural ecology describes human social activities generally in relation to the environments in which they are located; it recognises that the behaviour of people and the environments in which that behaviour takes place exist in mutually transformative relationships. In the case of the research reported here, dynamic interactions between individuals and the collaborative environment are mediated through an Internet-based resource. Through these interactions there is a constant interplay between, on the one hand, the immediacy of the experiences of the collaborating individuals, their 'in the moment', lived experiences, and, on the other hand, the collective understandings and abstractions shaped by received wisdom, disciplined knowledge and the affordances of the technological resources (Dillon et al., 2013).

In this study, it can be seen that immediate, 'in the moment' experiences and understandings derived from prior learning are constantly reconstructing each other as illustrated in both case examples above. The interplay between 'formalised' conceptual understanding and 'in the moment' perceptual engagement is evidenced through students attempts to bring together individual observations with collectively built knowledge and working with the reconceptualisations that emerged. Selecting, highlighting and negotiating detail in the processes of identification through analysis, argumentation and synthesis—this is experience validated through engagement with the affordances of the environment in the widest sense: physically, psychologically, socially, culturally and technologically (Dillon et al., 2013).

Motivational issues arise in group work that is tied to an externally directed task: it is easy to 'give up' because the responsibility for giving up cannot be attributed to one individual. The high incidence of 'flicking through' images suggests that the characteristics of low attention span and superficial engagement with subject matter, attributed to 'net generation' students, are worth further investigation (see Barnes, Marateo, & Ferris, 2007; Munitz, 2000; Schofield & Honoré, 2009). In all groups, all the members contributed to the dialogue, but in some groups, there was a dominant person, dominance typically associated with a claim to 'expert' knowledge coming from prior experience. 'Dominance' however, does not imply lack of dialogue, or suppression of the views of others. The peer support offered by the collaborative group was evaluated to be influential in species identification by helping the students notice things they would otherwise have missed (see also Kukkonen, Dillon, Kärkkäinen, Hartikainen-Ahia, & Keinonen, 2014).

In conclusion, this research has shown how categories of collaborative dialogue are utilised by students in identifying birds using an Internet-based taxonomic resource and how they draw on different forms of knowledge through the dialogue. There is circularity to the process of collaborative identification which involves the interaction of different categories of dialogue. Through the dialogue, prior experiences and knowledge are expressed and discussed relative to observations of the birds and the identification characteristics presented by the database. For all cases, the operational flowcharts revealed analysis and comparison to be the forms of dialogue that were most important in facilitating systematic movement through the database. By systematic movement, we mean the actions of the student groups working through a main category and sub-categories looking for options before advancing to another main category or randomly jumping between categories looking for possible choices. For all cases, the operational flowcharts revealed that assertion and argument frequently gave rise to the previously mentioned critical points in the identification but were also involved in their resolution. Forms of knowledge used in the dialogue are heavily influenced by the field the students are majoring in, experience in 'the field', and cultural context. Collaboration through the dialogue is both socially constructed and socially influenced. The main benefit to the students was through engaging in the collaborative dialogue in the process of enquiry. Use of the taxonomic database was of limited value in arriving at correct identification of species, but it did afford opportunities for students to explore variables through multiple 'in the moment' innovations when working with identification characteristics.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on Contributors

Jani Kontkanen, Msc., is a Ph.D. student in education and currently working as a university teacher in the School of Applied Educational Science and Teacher Education, Philosophical Faculty at the University of Eastern Finland. His research interests are in the pedagogy of ICT and ICT in education. His research currently focuses on class teachers' and class teacher students' ICT skills, and the use of iPads in senior secondary school teaching.

Sirpa Kärkkäinen, Ph.D., is a Senior Lecturer in Biology and Geography in the School of Applied Educational Science and Teacher Education, Philosophical Faculty at the University of Eastern Finland. She works with primary and secondary school teacher students and gives lectures focusing on science education especially biology, geography and environmental education. Her research areas focus on teacher education both at the primary and secondary school level, in particular inquiry-based learning and collaborative learning. In addition, more current research deals with issues such as informal learning environments, education about medicines and education for sustainable development (plant/animal identification and biodiversity).

Patrick Dillon is Visiting Professor of Applied Education in the School of Applied Educational Science and Teacher Education, Philosophical Faculty at the University of Eastern Finland and Emeritus Professor at the University of Exeter. His current research is in cultural ecology concerned with interactions between people and their environments which give rise to generative, transactional, relational and co-constitutional ways of knowing and being.

Anu Hartikainen-Ahia, Ph.D., is a Senior Lecturer in science pedagogy in the School of Applied Educational Science and Teacher Education, Philosophical Faculty at the University of Eastern Finland. She is interested in focusing her research on the student–student interaction in science classroom, especially in the context of inquiry-oriented instruction. In addition, her research areas focus on the use of social media in science education, and on the professional development of science student teachers. Recently she has been involved in medicine education projects in the health education context.

Mauri Åhlberg is Emeritus Professor at the University of Helsinki. His research is in biological education and education for sustainable development. He is a research director of NatureGate.

References

Åhlberg, M. K., Aineslahti, M., Alppi, A., Houtsonen, L., Nuutinen, A. M., & Salonen, A. (2014). Education for sustainable development in Finland. In R. Jucker & R. Mathar (Eds.), *Schooling for sustainable development in Europe* (Vol. 6). Heidelberg: Springer.

Barnes, K., Marateo, R. C., & Ferris, S. P. (2007). Teaching and learning with the net generation. *Innovate: Journal of Online Education*, *3*(4), 1–8.

Birchenough, A. C. (2002). Improving environmental knowledge. In *ENSUS 2002: Engaging the Public in Science*. Newcastle upon Tyne: School of Marine Science and Technology, University of Newcastle upon Tyne.

Boys, E. (2004). *What factors predict a child's knowledge of natural history, knowledge of conservation, attitude to conservation*. Unpublished student report. University of Cambridge.

Clark, C., Moss, P., Goering, S., Herter, R., Lamar, B., Leonard, D., & Wascha, K. (1996). Collaboration as dialogue: Teachers and researchers engaged in conversation and professional development. *American Educational Research Journal*, *33*(1), 193–231. doi:10.3102/00028312033001193

Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). The evolution of research on computer-supported collaborative learning. In N. Balacheff, S. Ludvigsen, T. Jong, A. Lazonder, & S. Barnes (Eds.), *Technology-enhanced learning* (pp. 3–19). Dordrecht: Springer Netherlands.

Dillon, P., Wang, R., Vesisenaho, M., Valtonen, T., & Havu-Nuutinen, S. (2013). Using technology to open up learning and teaching through improvisation: Case studies with micro-blogs and short message service communications. *Thinking Skills and Creativity*, *10*, 13–22. doi:10.1016/j.tsc.2013.06.001

Finnish National Board of Education. (2004a). *National core curriculum for basic education 2004 [Part III]*. Retrieved from http://www.oph.fi/download/47672_core_curricula_basic_education_3.pdf.

Finnish National Board of Education. (2004b). *National core curriculum for upper secondary schools 2003*. Retrieved from http://www.oph.fi/download/47678_core_curricula_upper_secondary_education.pdf.

Gotelli, N. J. (2004). A taxonomic wish-list for community ecology. *Philosophical Transactions of the Royal Society of London B*, *359*, 585–597. doi:10.1098/rstb.2003.1443

Järvelä, S., Volet, S., & Jarvenojä, H. (2010). Research on motivation in collaborative learning: Moving beyond the cognitive-situated divide and combining individual and social processes. *Educational Psychologist*, *45*(1), 15–27. doi:10.1080/00461520903433539

Jonassen, D. H., Peck, K. L., & Wilson, B. G. (1999). *Learning with technology: A constructivist perspective*. Upper Saddle River, NJ: Merrill.

Krange, I., Fjuk, A., Larsen, A., & Ludvigsen, S. (2002). Describing construction of knowledge through identification of collaboration patterns in 3D learning environments. In G. Stahl (Ed.) Proceedings of the conference on computer support for collaborative learning: Foundations for a CSCL community (pp. 82–91). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Kukkonen, J., Dillon, P., Kärkkäinen, S., Hartikainen-Ahia, A., & Keinonen, T. (2014). Pre-service teachers' experiences of scaffolded learning in science through a computer supported collaborative inquiry. *Education and Information Technologies*. doi:10.1007/s10639-014-9326-8

Louv, R. (2010). *Last child in the woods: Saving our children from nature deficit disorder*. London: Atlantic Books.

Mayr, E. (2004). *What makes biology unique?* Cambridge: Cambridge University Press.

Miles, M. B., & Huberman, M. (Eds.). (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.) London: Sage Publications.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction? What is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, *47*(4), 474–496. doi:10.1002/tea.20347

Mullarney, K., Svensson, L., Zetterström, D., & Grant, P. J. (1999). *Collins bird guide.* London: Harper Collins.
Munitz, B. (2000). Changing landscape: From cottage monopoly to competitive industry. *Educause*, *35*(1), 12–18. Retrieved from https://net.educause.edu/ir/library/pdf/ERM0011.pdf.
Nolen, S. B., & Ward, C. J. (2008). Sociocultural and situative research on motivation. In M. Maehr, S. Karabenick, & T. Urdan (Eds.), *Social psychological perspective on motivation and achievement. Advances in motivation and achievement* (Vol. 15, pp. 428–460). London: Emerald Group.
Palmberg, I. (2012). Artkunskap och intresse för arter hos blivande lärare for grundskolan [Student teachers' knowledge of and interest in species]. *Nordic Studies in Science Education*, *8*(3), 244–257.
Palmberg, I., & Kuru, J. (2000). Outdoor activities as a basis for environmental responsibility. *Journal of Environmental Education*, *31*(4), 32–36. doi:10.1080/00958960009598649
Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., & Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *Journal of the Learning Sciences*, *13*(3), 337–386. doi:10.1207/s15327809jls1303_4
Randler, C. (2006). Empirical evaluation of a dichotomous key for amphibian identification in pupils and students. *Journal of Science Education*, *7*, 34–37.
Randler, C. (2008). Teaching species identification – A prerequisite for learning biodiversity and understanding ecology. *Eurasian Journal of Mathematics, Science & Technology Education*, *4* (3), 223–231.
Randler, C., & Bogner, F. X. (2006). Cognitive achievements in identification skills. *Journal of Biological Education*, *36*, 1818–186. doi:10.1080/00219266.2006.9656038
Randler, C., & Metz, K. (2005). Zusammenhänge zwischen Artenkenntnis und Artnamen [Relationship between species name and species knowledge]. *Praxis der Naturwissenschaften – Biologie in der Schule*, *54*(6), 41–42.
Roschelle, J., & Teasley, S. (1995). The construction of shared knowledge in collaborative problem solving. In C. O'Malley (Ed.), *Computer-supported collaborative learning* (pp. 69–197). Berlin: Springer-Verlag.
Sarmiento, J. W., & Stahl, G. (2008). Group creativity in interaction: Collaborative referencing, remembering, and bridging. *International Journal of Human-Computer Interaction*, *24*(5), 492–504. doi:10.1080/10447310802142300
Savenye, W. C., & Robinson, R. S. (2005). Using qualitative research methods in higher education. *Journal of Computing in Higher Education*, *16*(2), 65–95.
Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 97–115). West Nyack, NY: Cambridge University Press.
Schofield, C. P., & Honoré, S. (2009). Generation Y and Learning. *The Ashridge Journal*, Winter 2009–2010, 26–32. Retrieved from http://www.ashridge.org.uk/360.
Sharples, M. (1991). Computer-based tutoring of visual concepts: From novice to experts. *Journal of Computer Assisted Learning*, *7*(2), 123–132. doi:10.1111/j.1365-2729.1991.tb00236.x
Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge.* Cambridge, MA: MIT Press.
Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning: An historical perspective. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 409–426). Cambridge: Cambridge University Press.
Tanaka, J. W., & Taylor, M. (1991). Object categories and expertise: Is the basic level in the eye of the beholder? *Cognitive Psychology*, *23*, 457–482. doi:10.1016/0010-0285(91)90016-H
Walton, D. (1998). *The new dialectic. Conversational contexts of argument*. Toronto: University of Toronto Press.
Yli-Panula, E., & Matikainen, E. (2014). Students and student teachers' Ability to name animals in ecosystem: A perspective of animal knowledge and biodiversity. *Journal of Baltic Science Education*, *13*, 559–572.