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Making a fictitious animal: 6-7 year-old Swedish children’s meaning making about evolution during a modelling task

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ABSTRACT
Whereas previous studies show that children are able to make meaning about evolutionary concepts within read-aloud contexts, little is known about how semiotic resources and interaction influence children’s meaning making about evolution. This study investigates children’s meaning making about evolutionary concepts during a modelling activity conducted after an interactive storybook read-aloud describing the evolution of a foraging trait of a fictitious mammal (the pilose). Forty children (13 groups) were videotaped as they produced a clay pilose model, while explaining how they thought their pilose would appear after inhabiting a ‘future’ environment (mountainous, snowy or forest). A multimodal analysis focused on how children demonstrated their meanings of seven evolutionary concepts described in the book. An eighth concept, ‘adaptation to environment’, was also often discussed. While all eight concepts emerged, the most frequent concerned survival and adaptation. The eighth concept appeared to serve as a synthesis of children’s interpretation of the storybook that highlighted the visible consequences of evolution. The children engaged five interactional resources, dominated by the interactional resource of communicating the concepts in direct relation to their produced pilose models. The findings shed light on how children’s representational and relational practices impact making meaning about evolution.

KEYWORDS
Evolution; early Childhood Biology Education; meaning Making; modelling

Introduction
In recent decades, evolution has become an established topic in elementary school education programmes in various countries. Concurrently, there have been attempts to find ways to introduce evolution to children at preschool and primary school levels through games (Campos and Sá-Pinto 2013), computer-based activities (Horwitz et al. 2013) and hands-on tasks (Nadelson et al. 2009). Although these directions provide interesting ideas on how to introduce evolution to young children, more evidence-based research is required to inform how evolution can be taught and how children at these levels make meaning about evolution.

In rising to the challenge of introducing evolution to young children, research by Emmons, Smith, and Kelemen (2016) and Kelemen et al. (2014) has shown that picture books serve as a valuable tool for introducing basic ideas of natural selection. In this regard, this research group has developed the children’s storybook How the Piloses Evolved Skinny Noses (Kelemen & The Child Cognition Lab, 2017). The book presents a narrative that focuses on the evolution of an animal foraging trait, namely the evolution of a skinny nose (‘trunk’) that enables the fictional pilose mammal species to access their primary food source, the milli bug.1

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The currently reported study follows on from a previous companion study (Frejd, 2019b) that explores how preschool class children make meaning when listening to an interactive read-aloud of the pilose book. This follow-on work investigates how the same children engage in a modelling activity involving crafting a clay pilose that inhabits a fictitious future environment different to that articulated at the close of the book. The work focuses on how the children make use of the storybook’s communicated scientific explanations of various evolutionary concepts in their meaning making about evolution in a different context – the modelling activity. Attention is paid to exploring children’s emerging representational and relational practices that are embedded in the collaborative and material attributes of the pilose modelling activity. In addition, the analysis explores how the children’s meaning making is related to the specific evolution concepts communicated in the book.

Theoretical background

Introducing evolution in early childhood education

A large proportion of research on evolution in primary education has focused on students’ conceptions about speciation in the light of Lamarckian principles, teleology, and essentialism (Berti, Barbetta, and Toneatti 2017; Berti, Toneatti, and Rosati 2010; Evans 2000; Samarakungavan and Wiers 1997). For example, Berti, Barbetta, and Toneatti (2017) interviewed third grade students before and after a ten-lesson intervention about the origin of species. Following the intervention, the students had learned about evolution in a fragmented manner and only a few students had learned about evolutionary mechanisms, findings that led Berti, Barbetta, and Toneatti (2017) to suggest that evolution should not be taught to children younger than eight years of age.

In contrast with Berti, Barbetta, and Toneatti (2017), other studies have proposed various methods for introducing evolution concepts to younger students. For example, Nadelson et al. (2009) have designed a series of standardised lessons for kindergarten and second grade children that include instruction and hands-on activities. The results indicate that children aged 5–8 were able to grasp concepts that were fundamental to understanding speciation and adaptation. Although researchers claim that early encounters with evolution might facilitate children’s further meaning making, teachers have limited pedagogical tools for addressing this abstract topic (Prinou, Halkia, and Skordoulis 2011).

Much of the earlier research on primary school students’ understanding of evolution has been designed with the objective of identifying and confronting children’s conceptions rather than focusing on their processes of meaning making (Prinou, Halkia, and Skordoulis 2011). In this study, we adopt a meaning-making perspective to explore children’s understanding and learning about biological evolution. Our approach draws on social semiotic views when considering children’s creation and communication of meaning as they negotiate various tasks using different materials as semiotic resources in small groups (see Frejd, 2018, 2019b). The adopted meaning-making perspective involves the intersection between various representational and relational practices that rely on social and material aspects in the production of knowledge (Mulcahy 2013; Evans 1999; Tang 2011). A meaning-making perspective entails meaning being able to be expressed both verbally and though non-verbal actions, such as gestures (Jewitt 2011). In this paper, we use the term interactional resource as an overall description for verbal (e.g. questions), non-verbal (e.g. gestures) and material (e.g. pictures) resources that enable meaning making.

Approaches in biology education that combine different representational, interactive and communicative practices often involve modelling activities (Treagust and Tsui 2013). For example, research by Nadelson et al. (2009) has explored the role of modelling in teaching speciation and adaption to young children. Their small-group inquiry approach showed that children’s modelling of similarities and differences in organism structure induced children to express their understanding through models in different activities. Moreover, research by Frejd (2018) has shown that six-
year-old children without any formal education in evolution could discuss and generate ideas about the diversity of big cat species when provided with materials, such as physical models and photographs of geographical representations.

Rationale and research aim

A large number of previous studies that aim to teach children about evolution have applied a systematic approach that often involves highly structured settings, such as pre-determined monological reading sessions and clinical interviews (e.g. Emmons, Lees, and Kelemen 2017; Emmons, Smith, and Kelemen 2016; Kelemen et al. 2014; Shtulman, Neal, and Lindquist 2016). A study by Frejd (2019b) has revealed that children are able to discuss and make meaning about evolutionary concepts from an interactive read-aloud. This exchange represents an unstructured and authentic classroom setting as opposed to a one-on-one read-aloud. This current paper follows on from this work by exploring how children make use of meaning acquired from the picture storybook How the Piloses Evolved Skinny Noses (Kelemen & The Child Cognition Lab 2017) during an unstructured group modelling activity. We hypothesise that doing so could provide complementary insights into additional factors that influence children’s meaning making of evolutionary concepts when compared with more structured approaches.

Emanating from a meaning-making perspective, the current study explores how children build upon experiences about evolution during a hands-on modelling activity. Specifically, we investigate how interactional and material resources influence the children’s meaning-making processes and their meanings about evolutionary concepts. The study is guided by the following research questions:

- What evolutionary concepts do children demonstrate during a modelling task, and how are the concepts communicated?
- How do different interactional resources influence children’s meaning making about evolutionary concepts during a modelling task?

Methods

Study setting and participants

When Swedish children turn six years old, they leave preschool and join preschool class, defined as a preparatory year prior to formal primary school. In this study, data was collected from three preschool classes at two municipal schools in eastern Sweden over the course of two weeks. In total, there were 40 six-year-old participants (16 girls, 24 boys).

Although learning about organisms’ adaptation to different habitats is not explicated in the curriculum until grades 4–6, the preschool class curriculum (Swedish National Agency for Education 2019) states that children should be taught sorting and grouping plants and animals as well as learning the names of common species. In addition, other aspects of the science discipline of relevance to this study are dealt with in preschool class. For example, all children should have the opportunity to investigate, explore, talk, and ask questions about science (Swedish National Agency for Education 2019).

Data collection

Thirteen groups of three or four children participated in two consequent activities, namely an interactive read-aloud of the storybook How the Piloses Evolved Skinny Noses (Kelemen & The Child Cognition Lab 2017) followed by a modelling activity conducted in the same groups. Subsequently, the first author, who is also a qualified teacher, spent a few days with the participants
in their classes to foster mutual trust. The first author performed the data collection and facilitated the modelling activity in all the groups. Videotaped data from the modelling activity, corresponding transcripts of multimodal communication, and photographs of the children’s models serve as the data corpus analysed in this paper.

Preceding interactive read-aloud

The read-aloud activity involved each group taking part in an interactive reading of the narrative picture storybook *How the Piloses Evolved Skinny Noses* (Kelemen & The Child Cognition Lab 2017). In consultation with three Swedish researchers in didactics, early childhood education, and bioscience, the original English text was translated into Swedish. The storybook concerns fictional animals called piloses. Across eleven double-paged spreads, the book describes the evolution of a skinny nose (a ‘trunk’) as a foraging trait that enables the piloses to access a milli bug food source, a narrative communicated through verbal text and large images that occupy 70% of each page spread (see Figure 1). The aim of the narrative in the book is to communicate specific concepts about evolution (Emmons, Lees, and Kelemen 2017) (see Table 1 later).

**Scientific content and narrative structure of the storybook**

At the beginning of the book, the pilose population exhibits both skinny and wide trunks. Climate change is then described, whereby the temperature of the environment increases. Concurrently, the piloses’ food source – milli bugs – retreats into narrow tunnels in the ground. Piloses with skinny trunks are able to reach down the narrow tunnels and obtain food. Piloses with wider trunks cannot reach as far down into the narrow tunnels, which causes them to become weak and sometimes die. The book describes piloses with skinny trunks as having two or more children, while piloses with wider trunks have no children or just one child - being able to eat affects fertility. The book repeatedly shows in both images and text that piloses’ offspring resemble their parents’ appearance. The text also explains that piloses born with wide or skinny trunks maintain this appearance throughout their lives. The book communicates a gradual increase in trait frequency by displaying several pilose generations. At the end of the book, the pilose population is dominated by piloses with skinny trunks. In the Swedish translation, a phrase was added at the end of the book: ‘What would happen to the pilose population if there was another change in climate? We will have to see what the future holds.’

![Figure 1. Placement of the children and the reader during the preceding read-aloud. The figure also shows a page spread in the storybook with approximately 70% occupied by images and the text at the bottom of the pages. (The image of the storybook is reproduced with permission from Tumblehome Learning, Inc.).](image-url)
Table 1. Evolutionary concepts coding scheme. The eight categories applied in the coding of transcripts from the modelling activity (based on Emmons, Lees, and Kelemen 2017).

<table>
<thead>
<tr>
<th>Biological concepts applied during coding</th>
<th>Examples describing how the concept is communicated in the storybook</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Trait variation inherent to a biological population</td>
<td>Piloses have wide or skinny trunks.</td>
</tr>
<tr>
<td>II. Ecological habitat and food-source change due to climate change</td>
<td>The weather changes and it becomes very hot. At the same time, the piloses’ food source (milli bugs) retreat down into narrow tunnels.</td>
</tr>
<tr>
<td>III. Differences in health and survival due to differential access to food</td>
<td>Piloses with skinny trunks can reach down the narrow tunnels, but piloses with wider trunks cannot. They become weak and sometimes die.</td>
</tr>
<tr>
<td>IV. Differential reproduction due to differential health</td>
<td>Piloses with skinny trunks have two or more children while piloses with wider trunks have no children or one child.</td>
</tr>
<tr>
<td>V. The reliable transmission of heritable physical traits across generations</td>
<td>Piloses' children resemble their parents’ appearance.</td>
</tr>
<tr>
<td>VI. The stability and constancy of inherited traits over the lifespan</td>
<td>Piloses that are born with wide or skinny trunks maintain this trait throughout their lives.</td>
</tr>
<tr>
<td>VII. Trait-frequency changes over multiple generations (adaptation)</td>
<td>There is a gradual change in trait frequency across generations. At the end of the book there are more piloses with skinny trunks than with wider trunks.</td>
</tr>
<tr>
<td>VIII. Adaptation to environment [not part of Emmons et al.’s original concepts]*</td>
<td>Piloses have different physical traits due to the nature of the environment in which they live.</td>
</tr>
</tbody>
</table>

*Concept VIII was added to the coding analysis since it arose frequently in the discussions.

**Interactive read-aloud**

The reading of the storybook was carried out interactively, whereby the children's reactions to the story were embraced and encouraged during the reading (Oyler 1996). The interactive reading approach often includes the reader sometimes pausing, rephrasing the text, and clarifying any uncertainties raised by the children, to ensure that everyone can follow the story. For example, the readers often paused at the first picture spread, which showed the variation in the population, and asked: ‘Do you see that they look different?’ The interactive reading approach adopted in this study differs from that proposed by Emmons, Lees, and Kelemen (2017), Emmons, Smith, and Kelemen (2016) and Kelemen et al. (2014), whose original reading approach was monological. The interactive read-aloud took approximately 10 minutes. The children and the reader were seated on the floor or on a couch, and all children could easily see and point at the book’s pictures (see Figure 1). Further details of the interactive reading activity are described in Frejd (2019b).

**Pilose modelling activity**

The modelling activity commenced directly after the read-aloud and was conducted in the following manner. Each group of children was seated around a communal table, where four pre-made clay models, resembling the piloses in the book, were placed in the centre (Figure 2a). Three of the pre-made models had longer, skinnier trunks while one had a wider, shorter trunk. Apart from the trunks, the piloses’ bodies differed slightly in colour and size. The pre-made models were positioned on two identical photographs resembling the dry desert environment that the piloses inhabited after a change in climate (see the description of the storybook above, Figure 2(b)).

Upon encountering the pre-made models (Figure 2(a)), many of the children spontaneously said that they were piloses and began to grasp, touch and handle them. In cases where this did not happen naturally, the researcher pointed to the figurines and asked whether the children recognised what they were. The researcher then reminded the children about the ending of the story with regard to possible environmental changes, stating that the book said ‘we would have to wait and see what the future holds’. Each child in the group was then handed a realistic photograph depicting a hypothetical changed environment that differed from the desert environment (Figure 2(b)). These photographs were described as future environments and comprised a snow-covered field with a tree line at the horizon, a rocky terrain with little vegetation and a stream flowing at the bottom of a steep canyon, or a forest with high coniferous trees and a moss-covered floor. The future
environments were randomly assigned to the groups, but children within the same group were assigned the same future environment.

In order to introduce and encourage the children’s interpretations of the future environments, the groups shared their perceptions of the features and environmental conditions of the assigned photographs. Next, the children were told that they were going to make a clay model of a typical pilose that lived in the environment in focus. The children were also told that when they had finished making their models, they should describe how their pilose ended up looking like it did. Each child in each of the groups modelled their own pilose and had access to white, yellow, light brown, dark brown and black modelling clay – coat colours that are common for animals with fur.

As the task unfolded, it was observed that some children found it difficult to mould the hard clay in the specific way that they wanted to. In assisting the children, the researcher demonstrated how they could start by forming the clay into a short cylinder, to which they could then apply pressure in order to mould the extremities. If the children asked for further assistance in beginning to make different
body parts, such as legs, the researcher supported this progression by shaping out short legs before handing the pilose back to the children and telling them to continue with their envisioned pilose.

During the modelling activity, the researcher probed the children’s ideas on what they thought a pilose would look like in the assigned future environment and why it would look that way. This type of dialogue often began with the researcher paying attention to the emerging or final traits represented in the children’s piloses as they took form, and then asking questions about the origin and functions of the represented bodily features.

The modelling task took 20–37 minutes, with an average time of 28 minutes. Each of the thirteen groups’ video recorded modelling sessions were fully transcribed verbatim in Swedish. Salient behaviours, actions and gestures observed from the video recordings were integrated into the transcripts (e.g. Hamo 2004). Datum examples of empirical relevance to this paper have been translated into English.

**Analysis of children’s meaning making about specific evolution concepts**

Based on the theoretical perspective applied in this paper, children’s meaning making about evolution during the modelling activity was studied by analysing the children’s verbal and non-verbal actions (Jewitt 2011). The seven specific biological concepts* communicated in the book were used as codes to analyse how children made meaning about evolutionary concepts (see Table 1) in the modelling activity.

The coding process consisted of purposefully reading through the thirteen transcripts for evidence of the biological concepts in the storybook demonstrated in the modelling task. Coding used interactional sequences, which are defined as a series of turns with the same science focus (cf. Hogan, Nastasi, and Pressley 1999). Each interactional sequence was only assigned to one concept which represented a complete theme (e.g. Amundsen, Weston, and McAlpine 2008). Statements that could not be assigned to the coding scheme were excluded from the analysis, since we were only interested in children’s meaning making about the specific meanings provided in Table 1. Any disagreements in researchers’ codings were discussed until a consensus was reached.

During the coding process, it became evident that the children made use of five different interactional resources when expressing the concepts, namely: 1) Responding to a direct question or further probing from the researcher, 2) Looking at or referring to the picture of the future environment, 3) Referring explicitly to the storybook, 4) Talking about their own modelled piloses and their appearances, and 5) Looking at, or talking about, the pre-modelled piloses.

**Results**

The findings are reported in two sections. We first reveal which evolutionary concepts children demonstrated during the modelling task and how they did so. Next, we describe how different interactional resources influenced the children’s meaning making during the emergence of the concepts.

**Children’s demonstration of evolutionary concepts during the modelling task**

Table 2 illustrates how the eight concepts were communicated by the children during the modelling task, by providing examples from the group discussions.

**The influence of interactional resources on children’s meaning making about evolutionary concepts**

Table 3 summarises the evolutionary concepts expressed in the modelling task and the interactional resources used. It also displays the intersection between interactional resources and evolutionary
Table 2. Demonstration of evolutionary concepts during the modelling activity. Descriptions of the concepts and examples of how they were communicated during the modelling activity. The fourth column includes examples of photographs and descriptions of the children’s clay models.

<table>
<thead>
<tr>
<th>Biological concepts</th>
<th>Description of how the concept is communicated during the modelling activity</th>
<th>Example</th>
<th>Children’s clay models</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Trait variation inherent to a biological population</td>
<td>Discussion about how there is variation between individual piloses with regard to the width of their trunks.</td>
<td>Researcher (R): Here (picks up the clay piloses) the piloses are as they looked at the end of the book. Mila: (Nods.) R: Do you see that they differ a little bit from each other (clasps the models while speaking). Some have a thick trunk and that one has a thin trunk. Albin: It’s not only one. There are three with thin [trunks].</td>
<td></td>
</tr>
<tr>
<td>II. Ecological habitat and food-source change due to climate change</td>
<td>Discussion about how change in the environment had led to different conditions for the milli bugs.</td>
<td>R: (Confirming another child’s immediate utterance.) An ordinary, normal forest, you say. (To Astrid:) What do you say about this picture, Astrid? What do you think it looks like here? Astrid: There is moss … and then you can eat more and so you can eat more ants [milli bugs] and there are anthills. And then you could also push a tree over, and then you could search there for food.</td>
<td></td>
</tr>
<tr>
<td>III. Differences in health and survival due to differential access to food</td>
<td>The children explain e.g. the shape of their pilose trunks, and the length of the legs with regard to enabling the pilose to find food or water.</td>
<td>Tyra: A trunk! R: Is it a trunk you have made there? T: Yes, a long one. R: Yes, it looks long. T: It [her pilose] would really get food (smiles).</td>
<td></td>
</tr>
</tbody>
</table>

(Continued)
### Table 2. (Continued).

<table>
<thead>
<tr>
<th>Biological concepts</th>
<th>Description of how the concept is communicated during the modelling activity</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV. Differential reproduction due to differential health</td>
<td>Associating piloses' access to food with fertility</td>
<td>Viktor (explaining why he has made a yellow pilose): Because the mums were born and they were yellow and then the babies were born and they were yellow, maybe ... R: Aha, so once there was a pilose mum who was yellow? V: Mmm (affirmative). R: And then, what? V: Then she had a baby because she ate a lot.</td>
</tr>
</tbody>
</table>

V. The reliable transmission of heritable physical traits across generations | Discussion about and modelling models showing that 'babies' resemble their parents' appearance. | R: Okay. And what about ... if this one [the adult pilose] has a baby, what will the baby look like then? Aleks: The same. |

Viktor’s clay models. A yellow mother pilose and its yellow child.
**Table 2. (Continued).**

<table>
<thead>
<tr>
<th>Biological concepts</th>
<th>Description of how the concept is communicated during the modelling activity</th>
<th>Example</th>
<th>Children’s clay models</th>
</tr>
</thead>
<tbody>
<tr>
<td>VI. The stability and constancy of inherited traits over the lifespan</td>
<td>Discussion about how the modelled piloses maintain the same appearances (e.g. coat colour) throughout their lifespan.</td>
<td>R: How did they get their hair on their backs?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stina: They grew, and then they got hair.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: Okay, so when they were born, did they have hair on their back then?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[. . ]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S: (Nods.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>R (Picks up Stina’s modelled pilose): And these cool colours, where did</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>they come from? Why does it [the pilose] have these colours?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S: It [the pilose] had those [colours] when it was born.</td>
<td></td>
</tr>
</tbody>
</table>

Stina’s modelled pilose showing multi-coloured skin, a black trunk, and a white fur coat. The colours of the pilose’s skin and fur coat are explained as being present from ‘birth’. **(Continued)**
<table>
<thead>
<tr>
<th>Biological concepts</th>
<th>Description of how the concept is communicated during the modelling activity</th>
<th>Example</th>
<th>Children's clay models</th>
</tr>
</thead>
<tbody>
<tr>
<td>VII. Trait-frequency changes over multiple generations (adaptation)</td>
<td>Discussion about how trait frequency changes over time.</td>
<td>Arvid: Those with thinner trunks were fewer, and then it got dry and then the trunks were thicker (wider) so they couldn’t get much food.</td>
<td>Children’s clay models</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: Mmm.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A: So, they [the wide-trunked piloses] became fewer.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: That’s right, but how… then there were more and more with thinner trunks. Why were there more and more with thinner trunks? Einar: Because these with short trunks (points at a pre-made pilose with a thin trunk), they could reach down into the narrow holes (points at the desert picture, Figure 1 bottom right). R: That’s right. Anything else? E: It was easier for them [to access food].</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: What was your thinking when you made your [pilose model[s]] legs? M: That they [the legs] should be a bit long so it [the pilose] can walk.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: It should have long legs so it can walk?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M: Mmm.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: Where should it walk to then?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M (looks at the mountain picture): Across here so it can find new bushes and get those bugs.</td>
<td></td>
</tr>
</tbody>
</table>

Mikael’s pilose, which has developed longer legs so it can walk across the land to find new bushes in which the milli bugs live.
Table 3. Summary of interational resources used when demonstrating evolutionary concepts (numbered I–VIII) in the modelling task.

<table>
<thead>
<tr>
<th>Activity</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responding to a direct question or further probing from the researcher</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td>9</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>Looking at or referring to the picture of the future environment</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Referring explicitly to the storybook</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Talking about their own modelled piloses and their appearances</td>
<td>-</td>
<td>16</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>-</td>
<td>20</td>
<td>-</td>
<td>47</td>
</tr>
<tr>
<td>Looking at or talking about the pre-modelled piloses</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>5</td>
<td>26</td>
<td>2</td>
<td>18</td>
<td>4</td>
<td>2</td>
<td>25</td>
<td>83</td>
</tr>
</tbody>
</table>

concepts. The most common evolutionary concepts displayed during the modelling task were Concept III: Differential health and survival due to differential access to food and Concept VIII: Adaptation to the environment, followed by Concept V: The reliable transmission of heritable physical traits across generations. The other five concepts only emerged between one and five times during the task.

When it came to using the interational resources, it was most common for the children to talk about their modelled piloses and their appearances. In fact, the modelled piloses were used as interational resources in more than half the occasions where evolutionary concepts were demonstrated. That is, the actual process of hands-on modelling was highly related to evolutionary concept demonstration (47/83). By contrast, looking at or talking about the pre-modelled piloses only influenced the expression of concepts three times (Table 3), which makes it a less common interational resource.

Some of the evolutionary concepts seem to appear more frequently in relation to specific interational resources. Concepts I, II and IV only emerged in relation to one specific interational resource. However, some concepts emerged in relation to more than one interational resource. For example, Concept V was equally distributed between talking about their own modelled piloses and their appearances, and responding to a direct question from the researcher. Furthermore, Concept III emerged in the use of all but one of the interational resources, which indicates that it is a compelling concept.

As stated above, the use of the modelled piloses was the most prominent interational resource. This particular resource induced all but one of the evolutionary concepts. This indicates that the hands-on modelling is highly related not only to evolutionary concept demonstration, but also to the emergence of multiple concepts.

Discussion

This work has shed light on how 40 children (assigned to small groups) make meaning about specific evolutionary concepts during a modelling task. The findings reveal that the children demonstrate the evolutionary concepts introduced during the read-aloud in their meaning making during the modelling task. The expression of concepts was manifested through both the children’s modelling activities and their verbal communication during the task. Hence, both the modelling activity interactions and the final models produced are representative signs of meaning making (cf. Nadelson et al. 2009; Treagust and Tsui 2013).

Utilising interational resources to demonstrate evolutionary concepts during a modelling task

As stated in the results (Table 3), Concept III: Differential health and survival due to differential access to food, Concept V: The reliable transmission of heritable physical traits across generations and Concept VIII: Adaptation to the environment were most commonly demonstrated. There is a pronounced difference in the frequency of expression of these three concepts (26, 18, and 25 times in total) and the other five concepts (1–5 times). One possible explanation for this difference is that the three concepts (III, V and VIII) are easier for children to talk about since they connect to
children’s everyday experiences. For example, children experience resembling their siblings and/or parents (V), being hungry or being told to eat food and become energised (III), or being tall enough to reach something high up and therefore having to adjust to the environment on an individual basis (VIII). The other five evolutionary concepts might not be as easily connected to the children’s own life situations, which might explain the less frequent demonstration of these concepts.

A further explanation for the low prevalence of concepts I, II, IV, VI, and VII is that they were not afforded by the design of the task. Concepts I and VII were noted to emerge infrequently. The emergence of Concept I concerned within-species variation. In the storybook, this concept is communicated by displaying piloses with either wide or skinny trunks. During the modelling task, this concept only emerged once. On one hand, this finding suggests that young children’s reasoning about variation within a population remains an enormous challenge, a finding that resonates strongly with the literature (Emmons, Lees, and Kelemen 2017). However, discussions about variation frequently emerged during the interactive read-aloud that preceded the modelling activity (Frejd, 2019b), which indicates that it is not necessarily the actual concept of variation that is challenging for children, but rather the context or the mode of delivery that plays a significant role in children’s meaning making (cf. Evans 1999). The expression of less frequent concepts, such as Concept I, might be encouraged by designing the task differently. For example, letting the children model a group of piloses could result in a discussion about variation within a population.

Concept VII concerns trait frequency changes over time, and only appeared twice. One explanation for this might be that the task itself forces the children to focus on one individual pilose, which may hinder them from talking about evolution at a population level (Frejd, 2018; also see Jeffery and Roach 1994). Another explanation could be that meaning making about variation of traits, as well as changes in frequency, remains extremely challenging for children (Emmons, Lees, and Kelemen 2017) (cf. Concept I).

In terms of the remaining three concepts (II, IV and VI), we suggest that they too could be enhanced if the modelling task included other opportunities to utilise interactional resources. As the results reveal, the emergence of some concepts was closely related to certain interactive resources. For example, discussions about ecological habitat and food-source change due to climate change (Concept II) only seemed to appear when accompanied by the pictures of the future environments and as the children referred to the storybook. However, the results also show that the actual hands-on modelling triggered the emergence of a multitude of concepts, creating a rich meaning-making environment. Thus, some of the interactional resources can be seen as ‘concept specific’, such as the pictures of the future environments that are only used in relation to Concept II (Table 3), while other interactional resources, such as the children’s own modelled piloses, encourage the emergence of a multitude of evolutionary concepts (five out of eight concepts, see Table 3). Nevertheless, none of the interactional resources used in this study cover all the evolutionary concepts. This finding suggests that a multitude of interactional resources contribute to a richer meaning-making process.

By developing the task or the interactional resources, ‘concept-specific’ resources could be developed to enhance the exploration of more evolutionary concepts. One way of further developing the modelling task is to allow the children to interact with several examples of future environments and model populations of piloses in more than one environment. One possible outcome of such a modification could be that the interactional resource ‘Looking at or referring to the picture of the future environment’ might be used to make meaning about variation (Concept I) or adaptation to the environment (Concept VIII). Another suggestion is to make the environment more realistic during the task by providing a physical 3D landscape (cf. Glenberg et al. 2004).
Unanticipated meaning making about evolution

A central finding in this paper is the emergence of Concept VIII, as an additional concept to the original seven identified by Emmons et al. (2017, Table 1). The concept suggests that piloses have different physical traits due to the nature of the environment in which they live (Table 1). Concept VIII was the second most frequently demonstrated concept in the entire study (25 times), and can be viewed as a ‘synthesis’ of the children’s interpretation of the storybook. Nevertheless, Concept VIII is not a mere ‘copy-and-paste’ description of the book. Many children suggested that the piloses had adapted to the future environment by giving their modelled piloses features that would enable them to obtain food from locations other than the tunnels (e.g. long legs so that the pilose could climb mountains to access bushes). However, when Concept VIII emerged, various evolutionary mechanisms such as variation and inheritance of traits were not mentioned. Instead, the children placed the visible consequences of evolution – adaptation of species to new habitats – at the centre of their meaning making. Nevertheless, traits other than the trunk were brought to the fore as foraging traits, depending on the future environment in focus. When demonstrating Concept VIII, the children tended to focus on their model’s ability to survive in the future environment, and survival was connected to being able to obtain food. In this regard, the findings of this paper confirm previous research studies on children’s transfer (Emmons, Lees, and Kelemen 2017), where children remained focused on traits relevant to foraging when explaining survival adaptations.

Since Concept VIII overlooks the presence of randomised mutations, there is a risk that children might believe that organisms simply adapt to their inhabited environments (cf. Lamarckian explanations of evolution and teleological reasoning). Even though it is not the intention of the author of the storybook (Kelemen & The Child Cognition Lab) to induce this type of reasoning, the children often do so. This finding thus suggests that even if teachers use a scientifically grounded narrative, children can still interpret the content in an unintentional manner. The mechanisms underlying random mutations are complex and difficult to grasp. Nevertheless, the fact that Concept VIII emerges from this study suggests that children are capable of making meaning about evolution in unanticipated ways.

In line with the unanticipated meaning making, we noted that the children focused on discussing food in various ways while exhibiting multiple concepts. As mentioned above, food is associated with – and acknowledged as being highly important in relation to – Concept VIII, as well as other concepts such as survival (Concept III), fertility (Concept IV), and being a catalyst for adaptation (Concept VII). The children’s preoccupation with food is in line with our previous discussion about children including their everyday experiences in their reasoning.

Indeed, being able to obtain food, as an essential life resource, is often presented as crucial in biological education literature (e.g. Legare, Lane, and Evans 2013). The relationship between food and survival indirectly points to ‘need-based’ (i.e. teleological) explanations for evolution, which, as discussed above, might be problematic. However, scholars such as Legare et al. claim that need-based reasoning nevertheless serves as a fruitful way to commence discussions on evolution. In this regard, we argue that children’s ability to forge a connection between species’ ability to obtain food in various habitats and their survival is essential for inducing meaning-making discussions about evolution.

Theoretical and practical implications of children’s meaning making about evolution

The current study suggests that children are able to make meaning about evolutionary concepts in a context that is different to the one where the concepts were originally introduced. A previous study that explored children’s understanding of evolutionary concepts at different times (e.g. Emmons, Lees, and Kelemen 2017) suggests that the ability to ‘transfer knowledge’ is crucial for understanding. This study has adopted a meaning-making perspective and indicates that meaning making about evolution involves the intersection of various complex representational and relational
practices that require social and material dimensions (Mulcahy 2013; Evans 1999; Frejd, 2018, 2019a, 2019b).

We believe that studying children’s meaning making about evolutionary concepts as they engage in a modelling task provides additional insights into how children’s meaning making can be explored. In this respect, the work shows that, when studying children’s learning about evolution, we cannot treat the learning process as a black box – merely studying input and output. Instead, we must also acknowledge how children make meaning of evolutionary ideas in action (cf. Siry 2013). In addition, when children take part in a hands-on activity and utilise interactional resources, other dimensions of meaning making become visible. The notion of interactional resources, as applied in this work, may contribute new theoretical directions for interpreting children’s meanings about evolution when they are expressed through several modalities.

The findings suggest that tasks, such as that applied in this paper, can encourage children to discuss evolution from multiple perspectives. Furthermore, by providing representations of environments, young children can communicate and make meaning regarding adaptation in a real science classroom environment (Frejd, 2018).

**Limitations of the study and future research directions**

While our approach involved purposefully using groups as the analytical focus, the findings of this study cannot make any claims about individual children’s transfer of meaning (cf. Emmons, Lees, and Kelemen 2017) or understanding about evolution (cf. Emmons, Smith, and Kelemen 2016; Kelemen et al. 2014; Legare, Lane, and Evans 2013; Shtulman, 2016). In addition, we do not explicitly investigate children’s ‘alternative’ ways of explaining evolution (cf. Evans 2000), since we focus on coding the meaning making of the biological concepts alone (Table 1).

As mentioned, we observed that the children often related their reasoning to food. One explanation for the children’s preoccupation with food could be the narrative focus on the evolution of a foraging trait and children’s everyday experiences. Therefore, it would be interesting to observe children’s models made after listening to a narrative that describes adaptations that do not link to their everyday experiences, such as building nests, going into hibernation, courtship behaviour or avoiding predators. This may shed light on how picture books promote children’s meaning making about adaptation.

Future research avenues could also explore the influence of the aesthetic dimension in the modelling activities with regard to children’s meaning-making processes. Furthermore, a development of the hands-on modelling task could include modelling more than one pilose, which would enhance discussions about within-species variation. Finally, the meaning-making perspective described in this study could be applied to other challenging scientific and mathematical domains, such as temporal and spatial scales.

**Note**

1. In line with the fictitious pilose animal, the milli bugs represent fictitious small insects in the storybook, which in biological terms would represent the small insect prey of mammals resembling piloses, such as mammals of the family Myrmecophagidae.
2. https://www.youtube.com/watch?v=nUyVd1pO3nI.

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