Students' Meaning-Making of Nutrient Uptake in Relation to Organizational Levels

RESEARCH

Using an Animation in Upper Primary School Science

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ABSTRACT

Previous research suggests that everyday expressions are commonly used in students' descriptions of nutrient uptake. This study investigate a classroom context in year 5 with a focus on signs of scientific meaning-making about nutrient uptake with an animation as a resource in two different schools. In one of the schools there was also a teacher review. The aim of this study is to investigate the pedagogical affordances of scientific terms and everyday expressions in the animation and in classroom teaching. Further, students' signs of scientific meaning-making at the meso and submicro organizational level in group discussions and written descriptions are analyzed and if taking part of a teacher review influenced the students' use of scientific terms and everyday expressions.The results show that the students who had a teacher review use everyday expressions at the meso and submicro level to a greater extent than the students who did not have an teacher review. The everyday expressions are often used as a kind of translation from the scientific terms in the students' drawings.

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INTRODUCTION

Students in primary school appear to understand the digestive system better than most other systems in the human body (Garcia-Barros, Martínez-Losada, and Garrido, 2011). Nevertheless, instead of describing digestion as a system involving several connected processes, many students describe digestion without mentioning the chemical breakdown. Instead food is described e.g. as being converted to "liquid food" (Cakici, 2005). Furthermore, previous research suggests that students generally find it difficult to connect processes relating to food digestion taking place at different organizational levels[1] in the body (Carvalho et al., 2004; Rowlands, 2004; Teixeira, 2000). Thus, we ask ourselves how we could help students to better understand digestion and nutrient uptake and to connect the processes taking place at different organizational levels to a meaningful whole. Research suggests animations might be useful to explicitly show how processes at different organizational levels are interconnected. However, research has indicated that animations often are too complex and contain too much simultaneous information to achieve meaningful learning for students (e.g., Tversky, Morrison & Betrancourt, 2002). On the other hand, research also shows that animations could be used successfully in learning certain aspects of science (e.g., Rundgren & Tibell, 2010). Another aspect of learning science is learning the language of science (Lemke, 1990). Research has shown that everyday expressions (often using metaphoric expressions) are commonly used in students' descriptions of nutrient uptake (Rowlands, 2004; Cakici, 2005; Jahic Pettersson, Danielsson & Rundgren, 2020). However, how to make use of everyday expressions in a way conducive to learning the science content, while simultaneously teaching the language of science, can be a challenging task for the teacher. This study investigate how teaching using an animation describing nutrient uptake, created with the intention to connect events taking place at different organizational levels, can be designed to achieve scientific meaning-making.

LEARNING ABOUT DIGESTION AND NUTRIENT UPTAKE IN CONNECTION TO DIFFERENT LEVELS OF ORGANIZATION

Biology spans phenomena from atoms to biospheres (Tsui & Treagust, 2013), processes that take place in a few seconds to thousands of years. Learning biology thus entails meaning-making about concepts regarding structures and processes that occur on spatial and temporal scales far beyond our field of perception. Coping with different scales creates difficulties in meaning-making both at a general level and at a level of detail, which contributes to the challenge of having to switch between scales or levels of organization in biological systems (Harrison & Treagust, 2000).

In learning about digestion and nutrient uptake, a common challenge is to make connections between processes taking place at different levels of organization (e.g. Snapir et al., 2017; Jahic Pettersson, Tibell & Löfgren, 2021; Knippels, 2002; van Mil, Postma, Boerwinkel, Klaassen & Waarlo, 2016; Meijer, 2011). Nutrient uptake is a process that spans at several different organizational levels (macro-, micro-, meso- and submicro level).[2] In Sweden (and many other countries), teaching about the human body and its organs, including the digestive organs, starts in elementary school and continues throughout school education (Swedish National Agency of Education, 2011). In particular the Swedish chemistry curriculum have formulations concerning food content, digestion and the importance of nutrients for the human health. However, students in grade 6 are not expected to formulate explanations at a cellular or molecular level since this is not stated in the curriculum (Swedish National Agency of Education, 2011). But international studies show that systems thinking with a focus on the different levels and their integration is increasingly occurring as a stated goal in biology teaching (Assaraf et al., 2013; Verhoeff et al., 2018).

Molecular processes in connection to nutrient uptake are abstract and too small to observe directly, hence, other ways to represent the phenomena must be used (Tibell & Rundgren, 2010). This leads to different kinds of simplifications. One common simplification is to focus on how waste products are handled in the gastrointestinal tract at the expense of nutrient uptake (Cakici, 2005). The implicit movement between different spatial scales is another simplification. Research indicates that students find it especially challenging to grasp the connection between what is happening at the observable macro level (i.e. food, intestines and organs) and the processes at the micro or submicro level (i.e. molecules and cells) (Broman, Ekborg, & Johnels, 2011; Rowlands, 2004; Teixeira, 2000). To make the invisible visible and to connect the macro level to the micro or submicro level by the use of different representations is a central aspect of science (Kozma, Chin, Russell, & Marx, 2000). To move from one level to another is something chemists do effortlessly, but for a novice learner, however, the same move is much more demanding (Chandrasegaran, Treagust, & Mocerino, 2011; Kozma, 2003). However, to explicitly show students how biological and chemical phenomena are associated with different levels of organization can facilitate their understanding and increased coherence across scales in students' explanations (Jördens, 2016).

LEARNING WITH DIFFERENT REPRESENTATIONS

Representations are semiotic resources that could symbolize, for example, concepts such as digestion or chemical bonding. Representations can be expressed verbally or in writing, with scientific terms or metaphorical expressions, with graphs, diagrams or simulations and animations (Tang et al., 2014). A representation is a way of expressing how one perceives the world and a way of showing one's understanding. Hence, a representation, like a model, is not comprehensive, it only pays attention to certain prominent features of a specific context (Kress and Selander, 2010). In order for a student to make meaning of often abstract scientific phenomena the student needs to associate learning science with "learning to think with representations" (Klein & Kirkpatrick, 2010, p. 88). According to Airey and Linder (2009), this is only possible through engagement with different representations and different modes of expressing the science content. Some common difficulties in chemistry and biology may be due to insufficient ability of the students to visualize structures or processes. Here animations can be a tool. Research shows that students' understanding of models benefits from visualizing processes at the submicro level (Talanquer 2009). In line with this, a study by Cokelez' (2012) indicate that students (12–13 years) in certain contexts prefer detailed abstract representations over simplified ones. Schönborn & Anderson (2006) concludes that an early introduction to visual representations and training in visual literacy skills could make valuable contributions to science education in early years.

THE USE OF ANIMATIONS IN THE SCIENCE CLASSROOM

The term animation refers to dynamic representations of dynamic processes or systems.

Animations can be interactive and represent output of simulations, or noninteractive and used more as movies to illustrate particular events or concepts. Understanding digestion and nutrient uptake may possibly be an area of science education which could benefit from the use of animations. Among the reasons for this supposition, we could mention the intangible nature of the processes as well as the complex interactions of different processes at different organizational levels in the body.

Rundgren and Tibell (2010) argue that animations cannot be completely realistic, and that they are neither self-explanatory. Therefore, they need to be complemented with other meaning-making sources, such as other visual illustrations and group discussions. Research on learning with animations, especially with a perspective from psychology or cognitive science, has come to the conclusion that learning from animations is often difficult, due to a surplus of information (e.g., Tversky, Morrison & Betrancourt, 2002). Those studies have often departed from the theory of cognitive load (Paas & Sweller, 2014). However, other research has shown that animations can be helpful for learning certain aspects of the scientific content (Sabelli, 2006; Heinrich & Kupers, 2019), for instance making transformations between 2D and 3D (Wu, Krajcik & Soloway, 2001; Rundgren & Tibell, 2010; Bohlin, Göransson, Höst, & Tibell 2017). Another aspect of learning science, in which interactive computer generated animations could be of value is to make complex content manageable (Jacobsen & Archidodou, 2000) and showing how events happening on different levels of organization are interconnected (Jenkinson, 2012).

THE AFFORDANCES OF DIFFERENT SEMIOTIC RESOURCES

Kress (2010) describes learning as an active and dynamic process that involves a constant work of interpreting and creating one's own understanding by connecting form and content in different ways, based on the resources we have available at the moment. At the same time, it means that meaning is always re-created, in connection with it being expressed or interpreted.

Learning is a process of change, which means a process of transformation where new representations are created and changed in relation to the existing ones (Selander & Kress, 2010). In students' meaning-making in science, it is possible to distinguish *signs of learning* (Selander and Kress, 2010). Signs of learning can be identified when students transform semiotic resources in a way that represents their understanding, for example through visual representations or everyday expressions. In order to describe the meaning-making process and the signs of learning displayed by the students, the concepts *transformation* and *transduction* (Bezemer & Kress, 2008; Kress, 2010) become important. Transformations refer to conversions of content in the same semiotic mode, for instance when students make a drawing based on an image. Transduction, in contrast, refers to conversions between modes, for instance description of an image in words.

The concept of *affordance* implies the meaning-making potential of different semiotic resources (Jewitt 2016; Kress 2010). All semiotic resources have variable potentials for meaning-making and they thus function differently in varying contexts for different people (Cope & Kalantzis, 2000). Varying semiotic resources in educational contexts have different *pedagogical affordances*, that is "the aptness of a semiotic resource for teaching some educational content" (Airey & Eriksson, 2019, p. 99–100). *Disciplinary affordance,* on the other hand, concerns "the agreed meaning making functions that a semiotic resource fulfil for a particular disciplinary community" (Airey, 2015, p. 103). Disciplinary affordance has a different role in science and in educational contexts since something (for instance, a certain representation) with high disciplinary affordance might have low pedagogical affordance in a science classroom, for instance a specific visual representation, or complex disciplinary term, such as *semi-permeable membrane* (***Figure 1***). Therefore, to contribute to students' meaning-making, the teacher needs to choose resources that are functional for the specific group of students, that is, resources that can be presumed to have high pedagogical affordance. Hence, with progress in learning, the teacher can use resourses with increasingly higher disciplinary affordance.

Generally, scientific terms have a high disciplinary affordance and need to be unpacked using everyday expressions, thereby increasing the pedagogical affordance for the students. A common way to increase the pedagogical affordances of a representation is to use simplifications. Generally, representations used in school science have reduced complexity compared to representations used in science. This strategy may naturally reduce the disciplinary affordances of the representations. However, certain studies (e.g. Rundgren & Tibell, 2010; Bohlin *et al.,* 2017) have shown that simplifications in some cases can also inadvertently reduce the pedagogical affordances of the representations, since deletion of e.g. connections between events taking place at different scales or organizational levels (i.e. *blackboxing* certain processes, only showing the outcome of the process) can make students' understanding more challenging.

EVERYDAY EXPRESSIONS AND SCIENTIFIC TERMS

An important part of learning science is learning the language of science (Lemke, 1990; 1998). This is done by gradually approaching the "new language" and making it your own. If we understand the subject content, we understand what is meant even if some words are omitted or the content, for instance, is expressed metaphorically (Lemke, 1990). But for the students, the content is usually new, and it can be a challenge to assess what is just a way of expression and what they are supposed to make sense of. Olander (2009) claims that students' use of everyday expressions in biology discussions, instead of scientific terms, for many students is an important part of the development of a scientific language; they will learn, replace and add scientific expressions to the everyday expressions. According to Lemke (1990) and Barnett (1992), students need to make use of their existing everyday language when they try to understand the language of science, thereby developing a *hybrid language*. Prain (2004) and Olander et al. (2018) also highlight the importance of the everyday terms in learning science. They claim that learning science is promoted by the teacher "unpacking" the scientific language by alternately explaining with an everyday term and a scientific term. However, the risk is that the teaching stops at the scientific terms being unpacked in everyday terms and not being repacked into scientific terms (Hipkiss, 2014). The goal is that the students learn to differentiate between everyday and scientific terms, and in which contexts to use them adequately. Aikenhead (1996) argues that teachers need to help students by clarifying the "border crossing" from everyday to scientific terms. According to Mortimer and Scott (2003), "the talk around the activities" (experiments, excursions, watching animations) is crucial for students' learning. The teacher has the role to create opportunities for the students to "talk about the activities" but also to introduce new concepts and support the students' use of scientific terms. Furthermore, in school, not all learning is recognized as learning. Selander and Kress (2010) argue that school may miss learning that could be valuable due to its rigid assessment rules which often is focused on written text and usage of scientific terminology.

Several studies show that students use a variety of metaphors to explain digestion (Cakici, 2005; Rowlands, 2004; Pettersson, Danielsson & Rundgren, 2020). For example, Olander, Wickman, Tytler and Ingerman (2018) describe that 14-year-old students express nutrient uptake in terms of nutrients "jumping" into organs. Since the everyday expressions analyzed in this study are largely metaphorical, we intend to focus specifically on the metaphorical aspects of the data in separate article (Jahic Pettersson, Danielsson & Rundgren, forthcoming).

Research shows that many of the metaphors and everyday expressions which students use also appear in textbooks (e.g. "gastric juice" and "stomach acid") (Danielsson & Selander, 2016). The role of textbooks for learning about digestion and nutrient uptake is often limited because they often do not contain images that represent the different scale levels in the different organ systems. Further, textbooks rarely clarify the links

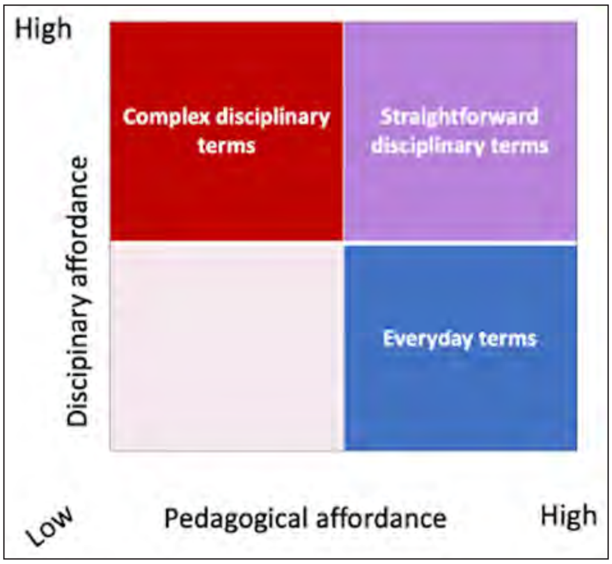

Figure 1 Scientific terms and everyday expressions as part of disciplinary and pedagogical affordance (developed from Airey & Eriksson, 2019).

between, for example, blood circulation and digestion (Carvalho et al., 2007; Granklint Enochson, 2008).

Teaching resources, as for instance textbooks, could be seen as semiotic resources in the classroom that are given their meaning in a social interaction where renegotiation of meaning and meaning-making takes place all the time in relation to other available resources (Selander & Kress, 2010). In this article, we focus on everyday expressions in relation to scientific terms as well as the meso and submicro organizational level, based on learning with an animation of nutrient uptake.

AIM AND RESEARCH QUESTIONS

The overall aim of this study is to expand the knowledge about the pedagogical affordances of scientific terms and everyday expressions in classroom teaching including an animation.

Research questions

1. What relationships are there between scientific terms and everyday expressions of nutrient uptake and the meso and submicro organizational level in the students' explanations?
2. What are the pedagogical affordances of everyday expressions in classroom teaching including an animation when describing nutrient uptake?
3. Which are the pedagogical affordances of the semiotic resources displayed in the teacher review[3]?

METHODS

DATA AND CONTEXT

We collected data at a school whose staff voluntarily agreed to participate in the study, partly because they were engaged in ongoing work with NTA-digital,[4] including use of a digital animation. The source of the science content in this study is an animation of nutrient uptake.

This specific computer generated animation is a narrated 'realistic' description of the path of food, from the mouth, through the digestive channel to the small intestine and showing how the resulting molecules are adsorbed through the cell membrane in the small intestine to the blood. The video could be started, stopped and replayed by the students. The animation was created for the NTA-project (see below). The animation was included in a situated learning situation at two schools. In school 1 a teacher review was included, and in school 2 there was no review. The procedure was otherwise identical in both schools. Two respectively in one school and three classes in the other school participated in the study. The first author visited the schools when they started the work with digestion and nutrient uptake, where the animation about nutrient uptake was in focus. The schools are public shools, located in two medium-sized municipalities in Sweden and are mixed gender grade 5 (age 10–11). The teacher in school 1 is specialized in science for upper primary school students and the teacher in school 2 is teaching science even though her teacher degree is specialized in social sciences. Both the teacher and the students were told that the aim of the research studies was to investigate what potential the animation had on the students' meaning-making about digestion and nutrient uptake.

The task started with the teacher and the students watching the approximately 8-minute-long animation with a narration together in the whole class. After seeing the animation, the teacher in school 1, together with the students, explained the six concepts (nutrient, villi, microvilli, amino acids, enzymes, cell membranes) that she had written on the whiteboard while they had seen the animation. The students were supposed to say what they remembered about these concepts from the animation, while the teacher developed their answers. Afterwards the students were supposed to work in groups. The teacher in school 2 had no lecture. Instead, immediately after they had seen the animation in the whole class the students started their group work. During the group work (with 2–4 students per group) the students discussed *how nutrients from the food can get out to all the cells in the body*. The students had access to the animation on an iPad (see **Figure 2**). Their group discussions were videotaped. Then the teacher divided the students into groups and started their group work. The two different teaching designs in schools 1 and 2, to have or not to have a review, was up to the teacher to decide, resulting in two different teaching designs in order to make meaning of the animation (**Figure 2**).

The data collected are transcriptions from the narration of the animation, from video recordings of the teacher review in school 1 and the students' group discussions. During group discussions, students were jointly asked to create multimodal (image and writing) explanations of how nutrients from the food are distributed to all cells in the body. The data collected included the animation, video recordings of the teacher's whole class review (in school 1) and the students' group discussions and multimodal texts. The narration of the animation and conversations between the students and the teacher

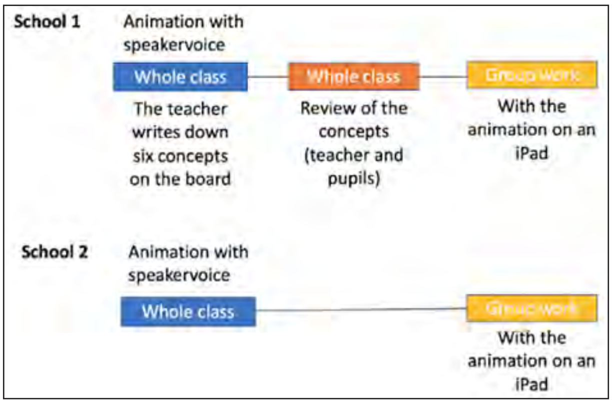

Figure 2 The teaching design.

(in Swedish) were all transcribed. Illustrative quotations in the following text have been adjusted to written language and translated by the authors into English. Omitted parts of the quotations are marked with slashes and dots (/…/). To ensure the participants' anonymity, the students are denoted with *S* and the teacher with *T* in the transcribed discussions.

Etical conderations

The requirement of confidentiality and the consent requirement is dealt with by blurring the face of the teachers and students in the picture so that the persons could not be identified. Further only those students who had an approved consent form from a guardian were allowed to participate in the study (Vetenskapsrådet, 2017). Also, the students were informed that their participation was voluntary and that they could cancel their participation at any time.

MATERIALS AND RESOURCES

NTA-digital and the animation

NTA-digital theme, "the human body", is a digital learning resource that contains of an interactive, three-dimensional model of the human body with integrated fact material and several animations (***Figure 3***). This learning resource is used by a large proportion of schools in Sweden (NTA Skolutveckling, 2021). In this study we focus on one specific animation. The animation with narration explains nutrient uptake. The animation is non-interactive and is thus used more as a movie, but it can be stopped and replayed. The animation illustrates biological processes and concepts by comments and explanations about what is shown visually.

Learning about the human body requires connections between structures and processes that extend from the molecular submicro level to the macro level in several steps in between (Jahic Pettersson, Tibell, Löfgren, 2021; Meijer, Bulte, & Pilot, 2013). The purpose of the animation is to highlight the connections between different levels or organization. The animation illustrates the digestion of food, all the way from the intake in the mouth until the uptake of nutrient molecules into the bloodstream. The emphasis of the animation is the nutrient uptake in the small intestine. No images are metaphorical since the goal when making the animation was to make it visually realistic (***Figure 4***). In the narration, metaphors and analogies are consciously used with the aim to facilitate students' meaning making of the complex processes of nutrient uptake. Both scientific terms and everyday expressions are used in the narration to explain the scientific concepts and processes. For example, the intestine is compared to as a *soft velvet*, the villi with *small folds* or *fluff [sw: ludd]*, the membrane proteins with *channels*, the enzyme functions with *scissors* that are *cutting*, and nutrients with *building blocks*.

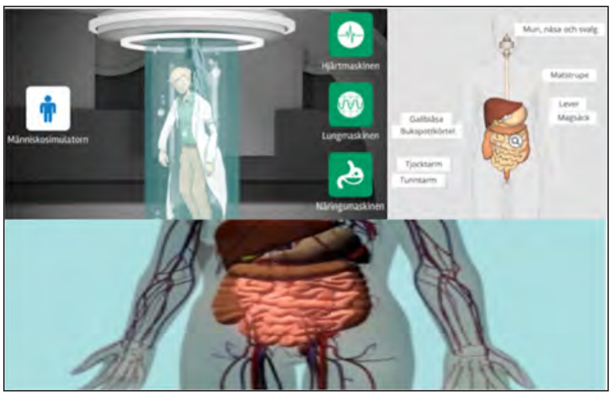

Figure 3 The model and digital platform of NTA-digital (NTA Skolutveckling, 2021).

DATA ANALYSIS

In this study students' signs of scientific meaning-making at the meso and submicro organizational level in group discussions and written descriptions were analyzed and if taking part of a teacher review influenced the students' use of scientific terms and everyday expressions.

We have analyzed students' use of scientific terms and everyday expressions in their oral and written explanations, including drawings. Furthermore, in their written explanations, we have analyzed how they use drawings and writing in combination to create explanations, in other words how the science content is transformed and/or transduced into the illustrated written explanations. When students use everyday

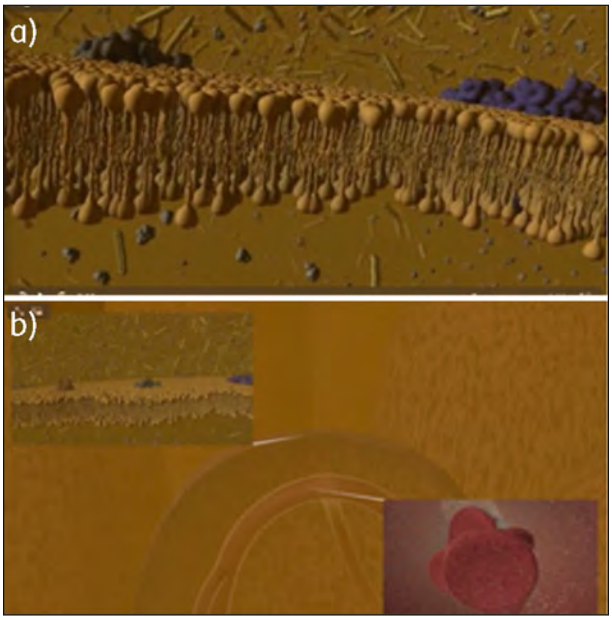

Figure 4 a) Screenshot from the animation where the image shows the cell membrane, i.e. a double layer of fat molecules with membrane proteins (NTA Skolutveckling, 2021). **b)** Screenshot from the animation where the image at the top left shows how the nutrient molecules are transported through the cell membranes in the intestinal cell and the capillaries and into the blood capillary (the image at the bottom right). The background image is intended to give an overview of one enlarged microvilli (NTA Skolutveckling, 2021).

expressions that correspond meaningfully to structures and/or processes related to the science content, we see it as a sign of scientific meaning-making. In contrast to signs of learning, as described by Kress and Selander (2010), which implies following change over time, the *signs of scientific meaning-making* described here constitutes snapshots of the students meaning-making in the classroom teaching. Further, the identified signs of scientific meaning-making are related to the pedagogical affordances of the semiotic resources available to the students. Therefore, in the analysis we regard signs of scientific meaning-making shown by the students as an indication of the pedagogical affordances of the teaching and the semiotic resources presented to the students (i.e. the animation, teacher review etc.). Therefore, we have also analyzed the usage of scientific terms and everyday expressions in both the animation and the teacher review (in school 1) in our analysis. Signs of scientific meaning-making are visible when students with everyday expressions, scientific terms and/or metaphorical expressions give scientifically meaningful explanations and describe specific processes.

In line with Jahic Pettersson, Löfgren & Tibell (2021) we focus the analysis on the most abstract part of the adapted high-resolution scale of organizational levels (***Figure 5***), namely the meso and submicro level.

As mentioned earlier, we are interested in students' signs of learning concerning nutrient uptake. When explaining digestion and nutrient uptake it is necessary to move between different levels of organization, from the macro level (the food) to the submicro level (the nutrient molecules) and everything in between. On the one hand we focus on how students construe nutrient uptake in relation to different levels of organization, and on the other hand we have a particular focus on the role of everyday expressions in relation to meaningful scientific content. Therefore, the animation, teacher's whole class review and the students' group discussions were analyzed in relation to scientific terms and everyday expressions and the connections to the meso and submicro organizational level (***Table 1***). Everyday expressions that are not highlighted are those that are well-established in the science classroom, as for instance *breakdown*.[5] However, the highlighted everyday expressions have a corresponding scientific term, such as channels for membrane proteins. Furthermore, everyday expressions are highlighted in italics and scientific terms in bold in ***Table 1*** and in the results. In ***Table 1*** there are examples of terms used in the animation, by the teacher and students.

RESULTS

In the result section we first give an overview of the students' usage of scientific terms and everyday expressions, subsequently focusing how these are connected to the meso and submicro organizational level, where students from school 1 and 2 are compared. Thereafter the focus is on the everyday and scientific sterms used in the teacher review in school 1.

In the excerpts are everyday expressions marked in italics and scientific terms in bold. As mentioned earlier, the students are denoted with *S* and the teacher with *T* in the transcribed discussions, and *Ex* if the quote emanates from the illustrated written explanations. There are

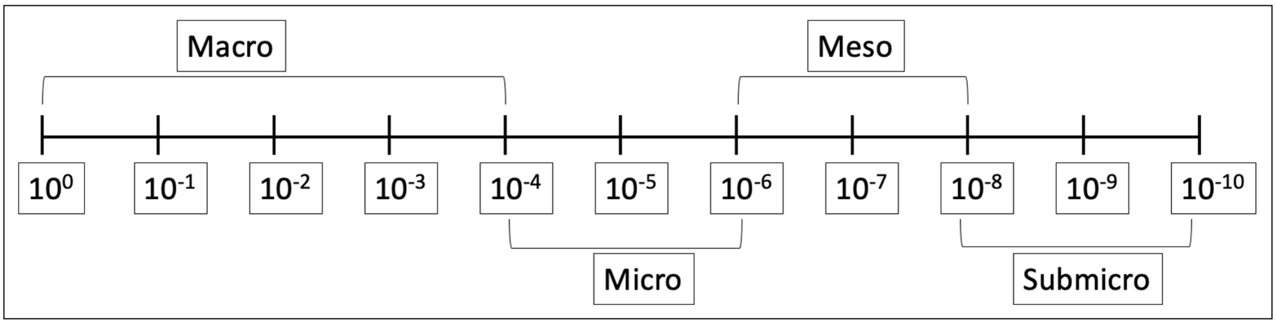

Figure 5 The scale (in meters) of the organizational levels in biological systems recognized in this article.

TYPE OF TERM	MESO	SUBMICRO
	$10^{-6} – 10^{-8}$ m	**$10^{-8} – 10^{-10}$ m**
Scientific term	**Microvilli**	**Nutrient molecules**
Corresponding everyday expression	*Fluff on fluff/protrusion on protrusion*	*Building blocks*
Scientific term	**Membrane proteins**	**Phospholipid molecule**
Corresponding everyday expression	*Gate/Channel/Entry/Door/Transport thing*	*Cotton swabs*

Table 1 Analytical tool for identification of everyday and scientific terms based on organizational levels.

examples that also include other levels of organization in addition to the heading they represent.

THE SCIENTIFIC TERMS AND EVERYDAY EXPRESSIONS IN THE STUDENTS' EXPLANATIONS IN SCHOOL 1 AND 2

This section presents the results from both schools (school 1 and 2) regarding relationships between scientific terms and everyday expressions at the meso and submicro level, and the pedagogical affordances of everyday expressions during teacher review in school 1.

The animation, together with its narration, explains nutrient uptake in the human body, and the emphasis is the nutrient uptake in the small intestine. The narrator uses scientific terms and explains some of them using everyday expressions. If one looks at the total proportion of scientific terms used by the students in the subsequent group discussions, the students in school 2 used more scientific terms than in school 1, while the students in school 1 used three times as many everyday expressions as was used in school 2 in their group discussions (***Figure 6***). As mentioned earlier, we have analyzed the usage of scientific terms and everyday expressions in both the animation and the teacher review (in school 1) in our analysis.

Examples from the illustrated written explanations

This section presents the results from both schools of how scientific terms and everyday expressions are connected to the students' written explanations contain both writing and drawings. In writing they often combine scientific terminology with everyday expressions, and both types are used either to describe structures or processes.

The students combine scientific terms and everyday expressions, either when they aim to explain a scientific term, or when they mix scientific terms and everyday expressions, as in example 1 and 2. In addition, this behavior is used both to describe structure (example 1) and processes (example 2).

Ex 1. "Each nutrient molecule has its own entrance" (see ***Figure 8***).

Ex 2. "The membrane proteins cause the nutrient molecules to enter the blood" (see ***Figure 9***).

In other cases, only the scientific terms are used. This is usually done to explain structural features and is observed either in descriptions given in writing (example 3) or as a short written explanation to the drawing (example 4 and 5).

Ex 3. "On the side of the intestinal wall there are villi and on the villi there are microvilli" (see ***Figure 9***).

Ex 4. The students draw sugar molecules and fatty acids like in the animation and write the name next to the drawings (see ***Figure 7***).

Ex 5. The students draw a piece of the intestine and write the scientific term villi (see ***Figure 8***).

There are also examples where only everyday expressions are used, and this behavior is observed both for structural descriptions (example 7) and to describe processes (example 7), and as short explanations to the drawings (example 6).

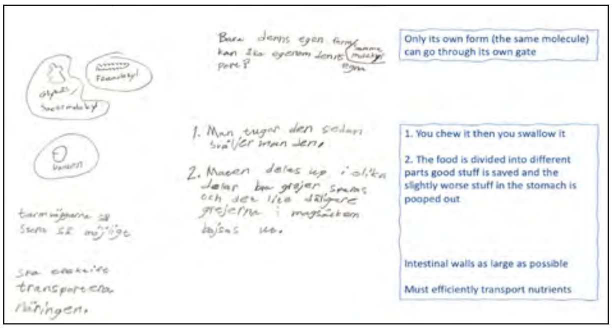

Figure 7 Written description with drawings by students from school 1.

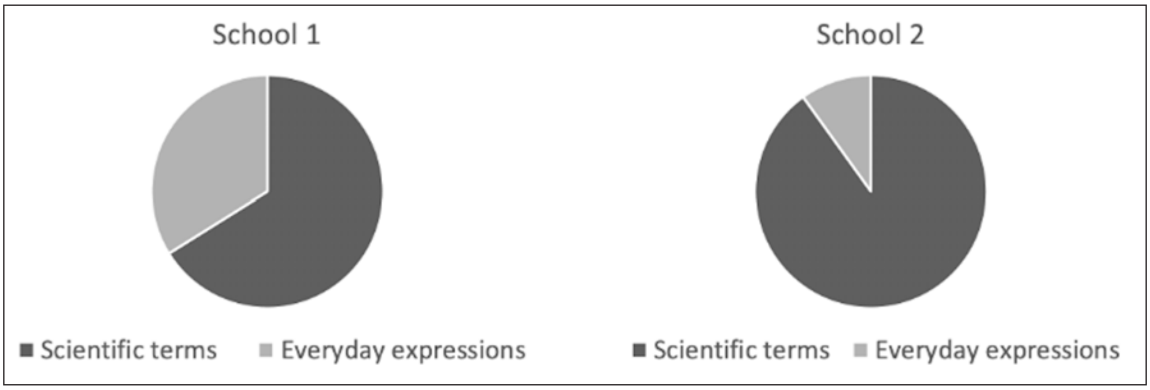

Figure 6 Proportion of scientific terms and everyday expressions used to explain the science content in the group discussions in school 1 and 2.

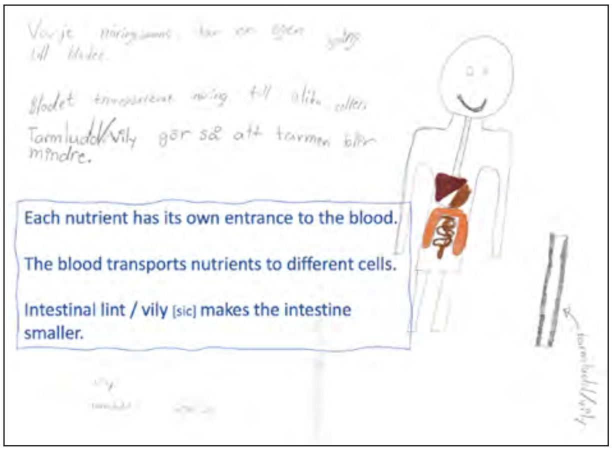

Figure 8 Students' group discussions without a preceding teacher review.

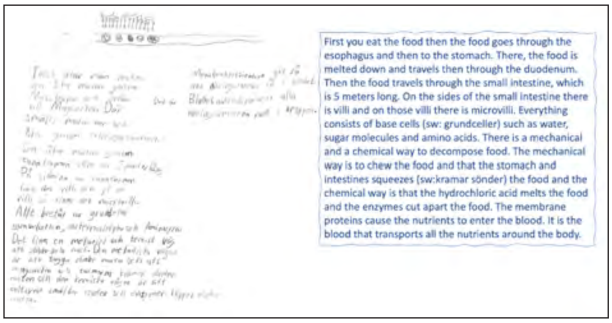

Figure 9 Students' group discussions with a preceding teacher review.

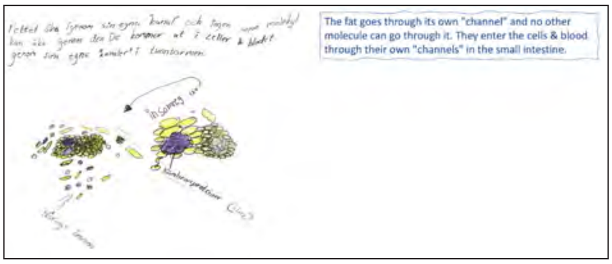

Figure 10 Written description with drawings by students from school 2. The students point out nutrients in the picture and they zoom in from one picture to the other where they point out the membrane proteins, however misspelled, but referred to as a rod in parentheses in the drawing.

> Ex 6. The students draw and write membrane proteins and explain its shape by writing "3D" and in parentheses the word "rod", describing the structural shape (see ***Figure 10***).

> Ex 7. "Only its own form (the same molecule) can get through its own gate" (see ***Figure 7***).

In summary, the students use either scientific terms or everyday expressions, or use them intermingled, as a hybrid language. For describing structures, scientific terms are most common while everyday expressions are usually used to describe processes.

Organizational levels and usage of scientific terms and everyday expressions

This section presents the results from both schools of how scientific terms and everyday expressions are connected to the meso and submicro organizational level. Hence, when we analyzed at what organizational level the students use scientific terms and everyday expressions, we found that the differences between the schools were observed at the meso and submicro levels (***Figure 11***). At the meso level, school 1 uses more everyday expressions and in school 2 the students use more scientific expressions. At the submicro level, the relations between everyday expressions and scientific terms are approximately the same.

Examples of students' explanations at the meso level

This section presents the results from both schools of how scientific terms and everyday expressions are connected specifically to the meso level. Even though the students in school 2 uses more scientific terms than in scool 1 they both use a combination of scientific terms and everyday expressions (everyday expressions are marked in italics and scientific terms in bold). In the following example a student explain the scientific term microvilli:

> S: /…/ on those villi there is like *protrusion on protrusion* called **microvilli**.

Several of the students from school 1 show signs of scientific meaning-making concerning processes occurring at the meso level by using everyday expressions as *gates* and *doors* relating to membrane proteins. These students also add submicro terms, such as names of nutrient molecules (water, fat) to their explanations:

> S: There were like *gates* and those *gates* they can only let in one kind. Here we have a *gate* for water

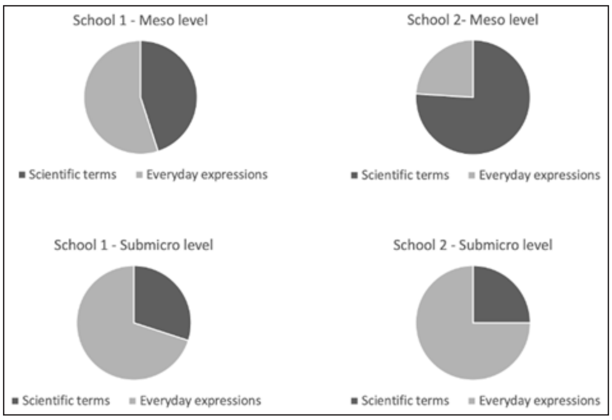

Figure 11 Proportion of scientific terms and everyday expressions at the meso- and sub-micro levels used in the group discussions.

and a *gate* for fat, one for sugar /... / (pointing at different membrane proteins).

S: Imagine as you said a *gate* or *a door*. In this *door or gate* there is a wall where only one kind of person enters, if there comes another person and sneaks behind, then they do not open the *doors*. Hey, they are geniuses /.../ Here is one and here and here /.../ Sheep can only go in there and elephants there /.../ they cannot sneak in a sheep with the giraffe, then you would notice it (pointing at different membrane proteins).

Also, in their text, associated to drawings, the students combine everyday and scientific terms (***Figure 7***). For instance, one of the student groups adds the submicro-term **molecule** in their overall everyday explanation of membrane proteins:

/.../ only its own *form* (the same molecule) can go through its own *gate*.

However, some of the groups in school 1 in fact used the scientific term membrane proteins in a context which displays signs of scientific meaning-making:

S: These are **membrane proteins**, for example **water membrane protein** – then they only let in water but no other nutrients, and the **membrane protein** for fat molecules only lets in fat molecules.

In school 2, everyday expressions were used at the meso level, for example by explaining that the food is broken down into molecules which have their own *transport thing* and *entrances* into the blood. These explanations with everyday expressions at the meso level occurred to a lesser extent compared to school 1. Actually, the students in school 2 used more scientific terms than everyday expressions at the meso level (see ***Figure 11***).

As shown in the text in ***Figure 10*** students in School 2 combine both everyday expressions (channels) and scientific terms (small intestine, cells, molecules) at different organizational levels (see ***Table 1*** for an overview of scientific terms and everyday expressions in relation to organizational levels):

S: The fat goes through its own *"channel"* and no other molecule can go through it. They enter the cells and the blood through their own *"channels"* in the small intestine.

Further, in their drawing these students pointed out and wrote the scientific meso-term **membrane proteins** (misspelled) in combination with the everyday expression *rod*. As mentioned, in their text above the drawing there was no scientific meso- term, but instead the everyday expression *channels* was stated (***Figure 10***).

Another example of a student text from school 2, i.e. without a teacher review, where students introduce the everyday meso-term *entrance* into their text (***Figure 8***). They also combine scientific terms and everyday micro level terms and thus suggesting that they understand that villi and intestinal fluff are used as two different expressions of the same thing "*intestinal fluff*[6]/**villy** [sic] makes the **intestine** smaller [sic]". That the student states that the villi make the intestine smaller may indicate a misconception. However, a possible interpretation of the answer could also be that the the surface enlargement provided by the villi makes the intestine smaller than it otherwise had to be.

At the meso level the focus of the everyday expressions is on functional similarity compared to macro and micro level where the focus was mainly on structural similarity. For instance, the students express the membrane proteins in terms of molecules passing through channels and having their own entry into the blood.

Examples of students' explanations at the submicro level

This section presents the results from both schools of how scientific terms and everyday expressions are connected specifically to the submicro organizational level. At the submicro level, the relative proportion between the students' use of everyday expressions and scientific terms are more or less equal between the schools (see ***Figure 11***). Also at this organizational level, the students from school 1 mix scientific terms and everyday expressions:

S: **membrane proteins**, water-membrane protein – then they only *let in* water but no other **nutrient molecules**.

S: The **enzymes** continue to *cut* and stuff so that it comes in its smallest distribution. They *cut* them so much so they become tiny. It continues to be *cut* down to its smallest form of food.

S: They *cut* the food so that it becomes smaller pieces and it comes to /.../ It becomes **sugar molecules, proteins** and so on /.../ The **sugar molecules and the proteins** go through *the doors* (points at the membrane proteins) and then it gets around in the blood /.../.

A student group in school 1 mainly use scientific terms in their text. But towards the end, the scientific submicro terms and everyday expressions are mixed (***Figure 9***): "**hydrochloric acid** *melts* the food and the **enzymes** *cut apart* the food".

At the submicro level just as at the meso level, the everyday expressions that the students use focus mostly on functional similarity. For instance, **nutrient molecules** *going through doors* and **enzymes** *cutting* food apart. However, the students in school 2 express themselves more similarly to the animation and especially at the submicro level with a focus on enzymes which are expressed with a mixture of everyday and scientific terms, such as *scissors* that *cut* (**the molecules**) in the food:

> S: The **nutrient molecules** must be as small as possible. They are *cut* into small pieces by the *scissors* in the small intestine.
>
> S: The **digestive enzymes**[7] act as tiny *scissors*/…/ they *cut apart* the **molecules** in the food.
>
> S: the **nutrient molecules** have their own transport thing or what should you call it- entry into the blood.
>
> S: when it comes in it must be as small as **molecules**, for us to get the **nutrition molecules** to the cells in the body.

The animation appears to succeed in communicating the importance of chemical degradation to nutrient molecules and the importance and selectivity of the membrane proteins for the transfer to the blood. Concerning the subject content knowledge, the importance of the successive degradation of food to nutrient molecules were often discussed by the students. The students noted that the nutrients had to be small to be able to be transferred to the blood. Another important component of the discussions was that the nutrients, after being transported over the mucosa membrane, were transferred to the blood and distributed by the circulatory system to the human body. This topic was mentioned, but not emphasized, in the animation. Moreover, the role of the blood in distributing nutrients in the body appeared to be known by the students. However, the process that was most thoroughly discussed in the students' group discussions was the transfer of nutrient molecules through the membrane proteins in the intestinal mucosa.

PEDAGOGICAL AFFORDANCES OF THE TEACHER REVIEW IN SCHOOL 1

This section presents results concerning the pedagogical affordances of a preceding teacher review from school 1. The teacher in school 1 identified the most unfamiliar scientific concepts and processes in the animation and explained them using everyday expressions, also using everyday expressions that arose spontaneously during the discussion with the students. At the macro and micro level, the teacher and the animation most commonly express the structural similarities in everyday expressions, such as the inner surface of the intestine is like a wet velvet soft pink rug and the surface of the intestine is full of folds and protrusions. The microvilli was also expressed as protrusions on protrusions or fluff on fluff.

However, at the meso and submicro levels the teacher introduced many other everyday expressions, such as protrusions, small folds and threads and fluff on the fluff to explain villi and microvilli. Another example is the *cotton swabs* (a term first suggested by one of the students) used to represent the phospholipids of the cell membrane, gates that let through different molecules for membrane proteins, *knocking on the gate* and *VIP-members* to explain the specificity of the membrane proteins. At the meso level the teacher is mainly explaining microvilli and is clearly inspired by how this is explained in the animation. She explains the structure of the microvilli in the animation, as *protrusions on protrusions*. Hence, scientific terms and everyday expressions are also combined at the meso level. The everyday expressions complement and explain the scientific terms.

> T: /…/ **microvilli** it was *even smaller things* like this, so if you think that on a *fold* like this there were *small folds* too, that was what they said *fluff on the fluff*. It is like *fluff*, although it is like *fluff on the fluff* as well.
>
> T: /…/ and **microvilli** are like *small threads that sit on the threads* kind of.

At the meso level the pedagogical affordance of everyday expressions relate to functional similarity, as compared to macro and micro level where the focus was mainly on structural similarity. The meso level is the most common level in the teacher's review since the teacher mostly talks about the cell membrane, and the membrane proteins and their function.

The teacher compares the membrane proteins with different *gates* for different molecules, explaining the function of the membrane proteins by knocking on students' desks, while giving the students the roles of different membrane proteins:

> T: /…/ it was like this, the one you say is black here it was like a *gate* you could say.
>
> T: /…/ then it is *a gate that lets through* **proteins** perhaps, and *a gate that lets through* **fat** for example, and another *gate that lets through* **sugar.**

T: /.../ then if I was sugar and I come and *knock on the gate* that lets through sugar. May I come in then? Yes I can, because I am the right one!

During the discussion in whole class the students come up with various explanations concerning everyday expressions that the teacher in many cases acknowledges:

S: /.../ You must be a *VIP member*!

T: Yes I have to be a *VIP member* on exactly the **protein** I usually run into, quite right!

In the excerpt below, the teacher acknowledges an everyday expression (cotton swab) which a student came up with when describing the phospholipids constituting the bulk of the cell membrane:

T: /.../ Exactly, they actually look a bit like *cotton swabs*, quite right.

The teacher then brings the cotton swab-term to all the other classes in school 1:

T: /.../ Do you know what they in class C said that the **cell membrane** looked like? It looked like *cotton swabs* they said, I thought it was quite smart actually.

At the submicro level, the teacher talks mainly about enzymes as *scissors* that *cut* the food into molecules, and by using scientific terms when she talks about the nutrient molecules:

T: /.../ the *scissors that cut* everything into smaller and smaller pieces of the food until you only have the small **nutrient molecules** left.

T: The **enzymes** *cut apart* everything so that we get all these tiny little nutrient molecules /... / then the body must *cut apart* it /... / The enzymes *cut apart* everything.

The teacher's expressions were to some extent inspired by the animation, but she also introduced her own everyday expressions, and she also repeated what some students had mentioned. However, at the submicro level just as at the meso level, the pedagogical affordance of everyday expressions is their focus on functional similarity.

DISCUSSION

The animation in our study brings to life the complex digestive process, following the food from the mouth to det blood vessels, and it aims to help students to understand the transitions between organizational levels. In addition, the animation focuses on the nutrient uptake in the small intestine, which is an often poorly described process in the teaching of digestion. According to previous research, animations can often be too complex (Tversky, Morrison & Betrancourt, 2002), causing cognitive overload (Paas & Sweller, 2014). The animation used in this study could be considered as complex and it describes digestion and nutrient uptake differently than the simplified illustrations in the students' textbooks. However, our results show that the students in our study appear to grasp most of the content relating to nutrient uptake from the animation and manage to display signs of scientific meaning-making in explanations, often using everyday expressions, which was meaningfully related to the subject content. This is in line with the conclusions of Rundgren and Tibell (2010), Cokelez (2012), and Bohlin, Göransson, Höst, and Tibell (2017), indicating that more complex descriptions in certain contexts can be more beneficial to learning than simplified ones. Students in primary school are not expected according to the curriculum (Swedish National Agency of Education, 2011) to be able to grasp the molecular realm of selective transport through the cell membrane and the functioning of transmembrane proteins. However, the students in our study were able to do this, using the pedagogical affordances of the animation and everyday expressions.

THE PEDAGOGICAL AFFORDANCES OF EVERYDAY EXPRESSIONS IN TEACHING

The usage of scientific terms in the animation is accompanied by translations into everyday expressions. This appears, in many cases, to explain the meaning of the scientific terms for the students. In fact, the students are using the everyday expressions mentioned in the animation either explanatory or as a translation of the scientific terms in their discussions and in their drawings. Our study thus confirms the important role of using everyday expressions in the process of meaning-making of science content for many students suggested by e.g. Olander (2009). We can also confirm students' use of a hybrid language mixing scientific terms and everyday expressions suggested by e.g. Barnett (1992). In most cases the students use the scientific terms and everyday expressions they find most appropriate for the moment in the prevailing circumstances, but this does not necessarily mean that they cannot express themselves in other ways (Cope & Kalantzis, 2000). When students use everyday expressions that correspond meaningfully to biochemical structures and/or processes, we argue that they show signs of scientific meaning-making. For example, when the students use everyday expressions in the description of specific transfer of different nutrient molecules through their specific membrane protein by imagining that there was a gate or a door in the cell membrane wall where only one kind of person could enter – if someone tries to sneak in, the doors will not open. In one instance, the students are pointing at the different membrane proteins in a paused scene in the animation (on an Ipad) and saying, "here is one and another one here". Meanwhile, they start to exemplify who can enter through the different membrane proteins that they are pointing at by saying "Sheep can only go in there and elephants there /…/ they cannot sneak in a sheep with the giraffe, then you would notice it". This clearly shows that the students have understood the specificity of the different membrane proteins. The students also became engaged in the discussions when they used everyday expressions, we believe that their engaged explanations could contribute to their meaning-making of the structures and processes of nutrient uptake. Students often also mix the scientific terms and everyday expressions in a meaningful way like for example: "The *digestive* **enzymes** act as tiny *scissors*… they *cut apart* the **molecules** in the food". These quotes also point to another quality that is characteristic of how students use everyday expressions.

Carefully used, everyday expressions can provide pedagogical affordance to understand the scientific content which the animation aims to explain (Airey & Eriksson, 2019; Olander et al., 2018). Further, if the teacher clarifies the "border crossing" from everyday to scientific terms and use everyday expressions in order to "talk about the activity" which in this case is the animation then the everyday expressions can also provide pedagogical affordances in the students' meaning-making process (Mortimer and Scott, 2003; Aikenhead, 1996). Prain (2004) and Olander et al. (2018) claim that learning science is promoted by the teacher "unpacking" the scientific language by alternately explaining with an everyday expression and a scientific term. However, as Hipkiss (2014) highlights, teachers using everyday expressions runs the risk of the teaching stopping at the scientific terms being unpacked in everyday expressions and not being repacked into scientific terms.

The co-construction of everyday expressions jointly by teachers and students in order to find a common way to talk about science content has been studied by e.g. Bellocchi and Richie (2011). In their study, teacher and students jointly construct a teaching context featuring role-play, in which an everyday description of trying to get into a gay bar (a word play relating to the term GABA neurotransmitter) as an analogical description of the working of ion channels. Similarly, our results show how the teacher and students collaboratively establish everyday expressions which enable them to describe processes relating to nutrient uptake using different semiotic resources (like knocking on benches), which the students subsequently translate into certain substances being "VIP-members".

RELATIONSHIPS BETWEEN THE MESO AND SUBMICRO ORGANIZATIONAL LEVEL IN THE STUDENTS' EXPLANATIONS

At the submicro level, the objects usually do not resemble anything that the students can relate to. Therefore, our interpretation is that they tend to use the scientific terms, such as *enzyme* or *molecule*. While at the meso level, students more easily tend to associate a membrane protein to a gate or a door since the focus is on the function or the process and then they seem to prefer to use everyday expressions like "that elephants cannot sneak in through a door specific for giraffes", or that enzymes act like scissors that cut the larger molecules to smaller pieces. In fact, the more an object can be compared to something the students can relate to, or the more complex a process is, the more students tend to use everyday expressions to make meaning of what they see in the animation. It is obvious that they use the everyday expressions to describe the structure or process. Therefore, the everyday expressions have pedagogical affordance for them.

In the student's written descriptions, the science content is transformed and tranduced into explanations using text and drawings in combination. The majority of the students draw to complement and explain processes at the meso and submicro organizational levels, such as nutrient molecules, the cell membrane and the membrane proteins, or to show the digestive tract and exemplify some feature that facilitates explaining the process. A common theme is the nutrient uptake of molecules (submicro level) and the specific membrane proteins (meso level). In ***Figure 7***, at the submicro level the different nutrient molecules are drawn in a way that resembles the molecular shape given in the animation. In ***Figure 10***, the students indicate the meso level by combining the drawing and the written text that describes the function of the membrane proteins where the drawing is in focus also shows the nutrient molecules at the submicro level. Great care has been taken to illustrate the cell membrane of the small intestine cells. The drawn cell membrane consists of phospholipids and two channel proteins. One of these allows fat molecules to pass (the other allows some other nutrient molecule). The students have also indicated other nutrients by mimicking their shape as they appear in the animation. The similarities between the students' drawings and how the structures are represented in the animation seem to indicate that the students think this transformation is easier to do than transducing the content into a written text.

DOES THE TEACHER REVIEW MAKE ANY DIFFERENCE?

Whether signs of scientific meaning-making can be detected depends on what semiotic resources are available to express a certain subject content (cf. Kress, 2010). First of all, many of the everyday expressions used by the students are also used by the narrator in the animation. This can be observed both in school 1 and school 2. The students in school 1, unlike those in school 2, had access to a teacher review and thus use a wider array of everyday expressions that relate to the explanations of the nutrient uptake given in the animation. In school 2, in contrast, the teacher let the students discuss on their own without any whole-class discussions together with the students.

We can see in our results that the students in school 1, in addition to the everyday expressions from the animation, also use many of the everyday expressions introduced by the teacher in the teacher-led review, and about three times as many everyday expressions as the students in school 2. In other words, the teacher-led review seems to have encouraged students to use more everyday expressions and not be hampered by not remembering or not feeling confident in using the scientific terms.

In summary, our results indicate that the students embrace many of the scientific terms and almost all the everyday expressions used in the animation during their group discussions. The teacher review appears to stimulate the students to a frank use of everyday expressions. At the same time the everyday expressions did not hinder them from, additionally, using scientific terms.

EDUCATIONAL IMPLICATIONS OF USING ANIMATIONS TO LEARN ABOUT ORGANIZATIONAL LEVELS

Our results indicate that using everyday expressions in a coherent manner and making connections between different levels of organization explicit (in the animation) can have high pedagogical affordances for students' meaning-making about nutrient uptake. To increase meaning-making, the teacher could also relate back to the everyday expressions that students use in connection with scientific terms in their discussions and thus contribute to students' learning, using the pedagogical affordances of the everyday expressions. For future studies, it would be interesting to have a whole class review after the group discussions where the teacher besides having a discussion of the pedagogical affordances of the everyday expressions also explicitly relate structures and processes to organizational levels (for instance using ***Figure 5***. and ***Table 1***). Through this, it would be possible to investigate if explicit linking to organizational levels in teaching could contribute to upper primary students' meaning-making.

Out of the organizational levels involved in learning about nutrient uptake, the meso and submicro levels has generally been regarded as too abstract and difficult for primary school students to grasp (Knippels, 2002; Meijer, 2011; Jahic Pettersson, Tibell & Löfgren, 2021). The consequence has often been that these steps in digestion have been avoided in primary science teaching, or explained using simplified descriptions, such as the food being "taken up" by the blood. However, in this study we intended to investigate whether it is possible to focus these levels and describe the involved mechanisms for upper primary school students. In fact, we have already shown that the most correct student descriptions of nutrition uptake in a national written test at upper primary level included the highest proportion of descriptions at the meso level (Jahic Pettersson, Tibell & Löfgren, 2020), and that the meso level seems to be essential for grasping connections between macro- and submicro-level processes and connections between digestion and circulatory systems. The animation used in this paper aim to show the entire process of nutrient degradation and uptake, and the narration intends to support the animations and transfer between organizational levels, and in addition, use everyday expressions to explain the scientific concepts, the visuals and the depicted processes. Our conclusion is that students at upper primary level can grasp central aspects of nutrient uptake from teaching using the animation as the main source of information. Furthermore, using everyday expressions in a coherent way can be beneficial to students' learning.

NOTES

1 In this article the term 'organisational levels' is used which corresponds to levels of biological organization.
2 See data analysis.
3 A teacher review was only given in school 1.
4 Swedish equivalent of Science and Technology for Children (STC).
5 *nedbrytning* in Swedish.
6 'Intestinal fluff' is a translation of a Swedish semi-scientific expression (tarmludd), referring to microvilli.
7 In Swedish "**matsmältningsenzymer**".

COMPETING INTERESTS

The authors have no competing interests to declare.

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