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Research article

Co-constructing novel science stories or reciting epic narratives? A case of science teaching in upper primary school

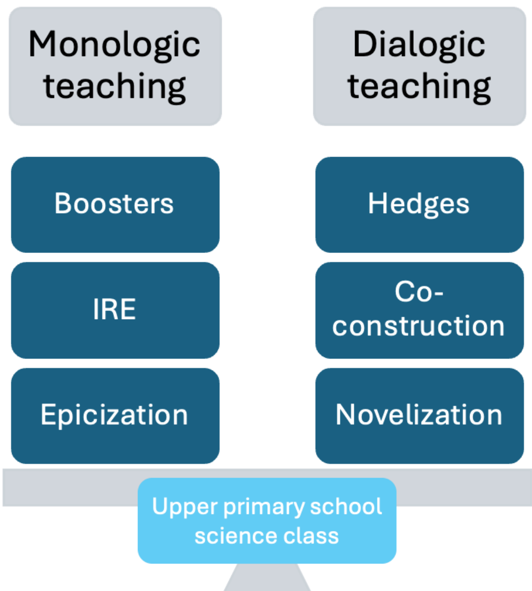
Lina Varg

Umeå University, Sweden

Abstract: Although research findings have emphasized the importance of students being engaged in dialogue and co-construction of science knowledge, implementing the teaching required to promote such engagement is challenging for teachers. Co-construction is crucial not only for students' understanding of science content but also for their familiarity with some of the attributes associated with the nature of science (NOS). Inquiry-based science classroom discourses could facilitate NOS familiarization processes by promoting creativity and collaboration in upper primary school. This article presents findings from a case study of how one teacher created and navigated opportunities for students' co-construction of science stories in a grade 6 class (age 12) working on the topic "Substances around us". To examine the classroom dialogue and the teacher's enablement of students' co-construction in class, observation data were gathered over seven weeks and analysed using principles indicative of classroom dialogue. Findings show that while opportunities for co-construction were created in science class through for example open-ended questions, the teacher's use of IRE, complemented with boosted communication for evaluation of student answers, often hampered dialogue and co-construction of novel science stories regardless of how the teaching was organized.

Keywords:
primary/elementary school science,
dialogue,
co-construction,
novel science story,
epic science story

Correspondence: lina.varg@umu.se



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1 Introduction

Science is marginalized in primary school in many countries, such as the U.S. (Bennion et al., 2022) and Sweden (Tytler, 2010). This marginalization can be seen through, for example, low prioritization of professional development for primary school science teachers and a lack of equipment and suitable premises for practical work. Combined with difficulties to encourage and maintain student interest in science (Anderhag et al., 2016), the marginalization could potentially lead to future populations with poor science literacy including a lack of awareness of the nature of science (NOS). NOS is defined as "the values and assumptions inherent to the development of scientific knowledge" (Lederman, 1992, p. 331). According to Forbes and Skamp (2013) there are six attributes of NOS stating that science is: inquiry-based, tentative, developmental, subjective, creative, and collaborative. Research emphasizes the importance of careful planning and explicit teaching of NOS throughout schooling (Schwartz et al., 2004). However, a good starting point for primary science teachers is to engage students in a classroom discourse where NOS attributes are included as a natural part of science education (McComas, 2020). Including NOS attributes in primary science classrooms may prove valuable, or rather necessary, in a society where biased, misleading information is freely disseminated and a distrust of science is increasing (Iyengar & Massey, 2019). In a literature search for research focused on students' understanding of NOS, Akerson et al. (2019) found that international studies specifically aimed at elementary school were scarce. This is unfortunate since research of upper primary school science provides important clues about why school fails to encourage student interest in, and understanding of, science content and NOS (e.g., Anderhag et al., 2016).

Inquiry-based teaching and decision-making activities are examples of useful methods for teachers aiming to familiarize students with NOS (McComas, 2020). Therefore, it was encouraging when a large, recent survey study reported that 44% of Swedish grade 6 teachers view laboratory work as the most important element in science education, compared to 22% who rated the learning of scientific concepts and theories higher in terms of importance (Lidar et al., 2019). However, when asked to identify which teaching practice most closely resembled their own, a majority of the surveyed teachers selected whole-class discussions (Lidar et al., 2019). Whole-class discussion is a broad term which includes everything from students answering recall questions to students reasoning around complex socio-scientific issues. In other words, such discussions could refer to activities aimed at involving students in decision-making. Another study found that, while Swedish primary teachers frequently mentioned classroom talk during interviews about their science teaching, using terms such as "discussing" and "reasoning" (Varg et al., 2022), their descriptions lacked clarity in explaining *how* such talk engaged students in communication. One example of student involvement in science class communication is through *co-construction*, which refers to iterative interactions resulting in a "joint production or construction of a particular knowledge, insight, understanding" (Menninga et al., 2022, p. 1501). Apparently teachers view talk as an important aspect of science teaching, but their ambiguity about if and how talk enables communication, such as co-construction, raises questions about what characterizes classroom talk in primary school science.

The present case study aims to expand the knowledge about teaching practices in upper primary school science by providing a thick description, or a snapshot, of one topic taught in one grade 6 class. More specifically, the study concerns whether classroom communication carried out through different teaching practices enables students' co-construction of novel science stories (van Eijck & Roth, 2013), and if so how. Teaching practices, in this case, refers to how the teaching is organized, and whether it is student- or teacher-centred. Teacher surveys and interview studies, such as those previously described, are limited as methods for studying the implementation of classroom teaching practices (Molbæk & Kristensen, 2019). Therefore, I used classroom observations to study how one teacher created and made use of opportunities for students to co-construct science knowledge, and learn about science, i.e. NOS. Most classroom interactions occur between teacher and student (Howe et al., 2019) and the present study contributes knowledge about how such interactions may form and develop in different classroom teaching practices. The study answers the following research questions:

- How is the teaching organized over seven weeks of upper primary science education on the topic "Subjects around us"?
- How do different teaching practices affect the teacher's opportunities to engage students in co-construction of novel science stories in primary school science class?

2 Background

2.1 Science stories in science education

Teachers in every science classroom at every school convey implicit and/or explicit messages about NOS (Clough & Olson, 2004; Oliveira et al., 2012) by expressing their view of science in the form of companion meanings (Östman, 2013). Often, teachers share the naïve view of NOS that is common throughout society, for example regarding subjectivity and the meaning of scientific theories (DiGiuseppe, 2014; Galili, 2019). A closer look at Swedish compulsory school science teachers shows that a majority view science as an endeavor greatly influenced by subjective factors (Leden et al., 2015). However, their talk about science teaching usually revolves around science as a set of objective facts and the teachers themselves identified this discrepancy between their views of science and science teaching as problematic (Leden et al., 2015). Teachers tend to rely on science textbooks which frequently reproduce the same well-established view of NOS, for example by communicating scientists' work as uncomplicated (at least for the scientist) and linear processes leading straight from hypothesis via observations to the truth (Bensaude-

Vincent, 2006; van Eijck & Roth, 2013). The representation of scientific work as a flawless production of truths could be considered one of several styles of science storytelling (Grobstein, 2005). This narrative style results in epic science stories which portray scientists not as ordinary people but rather as solitary heroes in search of the truth, presenting scientific discoveries as objective facts (van Eijck & Roth, 2013). The production of epic science stories which van Eijck and Roth (2013) referred to as *epicization* aims to replace *heteroglossia*, or the presence of many voices and ideas, with a *unitary language* communicating science (Bakhtin, 1981). In science, such a unitary language, or "concrete verbal and ideological unification and cultural centralization" (van Eijck & Roth, 2013, p. xix), has the highly relevant purpose of rationalizing and reducing misinterpretation of science communication. However, when epics enter and dominate the science classroom discourse, favoring reproduction of the established science representations, creativity is impeded while students' recollection of stated facts is promoted (van Eijck & Roth, 2013). Such well-known science representations are communicated through speech and text, but also through so called *inscriptions* which are used to illustrate science and include images, models and diagrams (Latour, 1987). Inscriptions are powerful for reproducing epic science stories and the more complex they are, the more resistant they are to deconstruction and meaning-making among outsiders (van Eijck & Roth, 2013). Through inscriptions, "scientific representation becomes a black box, and it takes a lot of effort to unpack what others have enclosed in them" (van Eijck & Roth, 2013, p. 7). In addition to the use of inscriptions, verbal and ideological unification is maintained in science classrooms through transmissive teaching including the well-known interactive pattern IRE, initiation-response-evaluation, (Mehan, 1979). In this practice teachers ask questions and students answer with recalled facts, after which the teachers evaluate the answers in terms of right or wrong. The use of IRE in science class is "at the very heart of the linguistic construction of knowledge, that is, at the construction of science as a unitary system" (van Eijck & Roth, 2013, p. xxi). It promotes the epic by encouraging memorization and recall while counteracting reflective NOS instruction and distracting students from familiarization with attributes of scientific work (McComas, 2020).

To increase students' awareness of science as a complex undertaking of regular people, rather than as an establishment of irrefutable truths obvious only to anonymous, objective scientists, science stories could be composed in a *novel* narrative style which allows several voices to be heard (van Eijck & Roth, 2013). The openness of novel science stories promotes a more accurate view of NOS as tentative, developmental, subjective, creative, and collaborative rather than communicates science as a collection of static facts for students to memorize. Engaging students in co-constructing novel science stories enables their exploration of perspectives of science that are less anonymous, mythical and objective and more creative, dynamic and relatable. The novelized view of science and scientists' work (NOS) is facilitated when teachers introduce scientific models, theories, and laws as expressions of thoughts "by some *person* who can be identified or at least envisioned" (Sutton, 1992, p. 80, original italics). Making students aware of the similarities between their and scientists' attempts to understand and explain the world around them, in that both are influenced by personal values and experiences, could contribute to a more refined understanding of NOS (DiGiuseppe, 2014). Students who are active in classroom communication learn to formulate, represent, and make meaning out of the science they encounter in class.

2.1 Dialogic teaching promotes co-construction

Through dialogue, induced by for example open-ended questions, students can express varied perceptions of science which are useful as a basis for co-constructing novel science stories in class (Alexander, 2020; Menninga et al., 2022). Teachers who create and support dialogic discourses promote heteroglossia in class by encouraging students to make interpretations and express, question, and discuss different ideas. Such a discourse counteracts the unitary language of established science which students are encouraged to recite in epic, or authoritative, classroom discourses (Mortimer & Scott, 2003; van Eijck & Roth, 2013). Van Zee and Minstrell (1997) advocated the use of students' own words in "extended series of questioning exchanges that help [them] better articulate their beliefs and conceptions" (p. 209). During such exchanges, the teacher could scaffold using so called *hedges* (e.g., "I think", "maybe") which open for continued dialogue and co-construction of science stories, or *boosters* (e.g., "absolutely", "that's right") which are common in IRE-exchanges and possibly ignore students' contributions to continued co-construction by evaluating answers as correct or incorrect (Oliveira et al., 2012). Epic science stories are promoted by boosters which indicate whether the students' responses agree with the story presented by teachers and teaching materials. When the feedback to student responses instead is provided through hedges, students' own voices are allowed to co-construct novel science stories in a process that utilizes several NOS attributes (e.g. science as tentative, developmental, and creative).

The benefits of dialogue as a means for students' co-construction of novel science stories and grasping of NOS are convincing; yet implementing dialogic teaching is challenging (Watters & Diezmann, 2016). For example, there are tensions between dialogic teaching and the authoritative curricular goals that govern teachers' work (Clarà, 2021). Teachers also face challenges when attempting to keep track of, and connect, multiple student ideas that are not communicated in sequence (Vrikki et al., 2019). Yet another aggravating aspect is that while teachers may view co-construction as important, they may also consider discussions as a waste of time that could be spent teaching facts instead (Wells & Arauz, 2006). In summary, dialogue is necessary to involve students in co-construction of novel science stories, which in turn paves the way for a more nuanced view of NOS. This case study offers a glimpse into how one primary school teacher creates and navigates the opportunities for novelization in a grade 6 science class.

3 Methods and analysis

Since the concepts of epic and novel science stories in science teaching have not yet been explored, the present study was designed as an exploratory case study. Exploratory case studies are appropriate to use in early investigations of an object, when there are yet no findings to hypothesize from (Yin, 1994). I used data from audio-recordings and classroom observations to analyse the opportunities for students to engage in co-construction of science stories (Menninga et al., 2022). The analysis consisted of both deductive and inductive processes. The pre-established dimension *activity structure* (Garnier et al., 2011) and concept of *dialogic principles* (Alexander, 2020) were used as tools in a deductive analysis of audio and observation data. Through inductive analysis the presence of epicization and novelization in class, as well as the acknowledgement or promotion of NOS attributes, were exposed. In this analytical process the concepts of boosters and hedges provided useful concepts as the teacher's use of them were indicative of different narrative styles of the science story.

3.1 Participants and setting

To recruit study participants, I sent an e-mail request to a group of upper primary school science teachers previously interviewed (Varg et al., 2022). Several of these teachers had expressed an interest in continued participation in science education research. The participating teacher, referred to herein by the pseudonym of Anna, was planning to teach a topic deemed appropriate for the purpose of the study. This topic was entitled 'Substances around us' and revolved around the elements and chemical compounds in our surroundings, as well as human exploitation of natural resources. Abstract themes such as atomic theory, and concrete themes such as the use of fossil fuels, provided opportunities for varied teaching which is considered advantageous in observation studies (Stodolsky, 1984).

Anna had worked at the same school in a small Swedish town since graduating as a certified grade 4–6 teacher in science, technology, and mathematics 2.5 years earlier. Approximately 360 pupils from varied socioeconomic backgrounds attended the primary school (ages 6–12) and Anna currently taught the observed grade 6 science class twice a week: 45 minutes on Mondays and 30 minutes on Thursdays. The 22 students, who have been given pseudonyms in the result section, were enrolled in their last semester of primary school. Anna described the class, which she had taught for 2.5 years, as well functioning with a positive learning environment. Science lessons were conducted in the students' so-called 'home classroom' which was equipped with a sink and water faucet, a smartboard, and a document camera used to project everything from demonstrations to textbook pages. The room had large windows and was small and crowded, which did not appear to be problematic, since the students mostly sat at their desks. Anna skilfully used the smartboard to show for example presentations and videos. At the start of every lesson, Anna also informed the students about the "lesson objective" which she formulated as learning goals, for example, “Know what minerals and ores are” (Lesson 4). The objectives were presented as something that the students were expected to learn or achieve during the lesson.

I visited Anna, a teaching assistant (pseudonym: Maria), and the students in class to inform them about the purpose of the study and their rights as participants (Swedish Research Council, 2017). I encouraged them to question or comment on the information given, then or afterwards via Anna or e-mail. A letter containing the same information was signed by the students’ parents and Anna to give consent to participation.

3.2 Data gathering and analytical approach

I observed and audio-recorded one lesson per week for a total of seven weeks. I used review sheets to collect data around teaching practices (Appendix A). The review sheet coding scheme was inspired by the idea of lesson segments (Burns & Anderson, 1987), which can be understood as time-separated units “with a particular focus or intention” (p. 31). Lesson segments were also used by, for example, the researchers conducting the TIMSS 1999 video study (Garnier et al., 2011). After reviewing the extensive coding scheme (Garnier et al., 2011), the following dimensions were considered relevant to the current study and were therefore selected for use in the review sheets: *Phase*, *Public speech*, *Activity function*, *Activity structure*, and *Social organization* (Table 1). In the review sheets, each lesson was divided into 2.5-minute chunks to facilitate the recording of time spent on different codes. In the review sheets, each lesson was divided into 2.5-minute chunks to facilitate the recording of time spent in different organization of teaching. For this article I analysed the distribution of different activity structures and social organization. In addition to the review sheets, I transcribed the recordings after each observation and combined the transcripts with written observation notes resulting in approximately 60 pages of narrative records.

Table 1. Dimensions and codes for lesson observations

Dimension	Codes	Additional information
Activity structure (AS)	Whole-class seatwork	Refers to segments in which all students are seated at their desk and the whole class is involved in the same activity.
	Whole-class practical work	All students are involved in the same practical task manipulating objects, most often this type of work means teacher demonstrations.
	Independent seat work	All students are seated at their desks, working in different constellations (SO) such as individually or in pairs.
	Independent practical work	Students are engaged in independent practical tasks manipulating objects, either individually, in pairs or in small groups.
Social organization a (SO)	Individual Pair Group	Refers to the social organization of pupils during independent work.

[a] *conducted in one of three social organizations*

Two different analyses were enabled from the data using lesson review sheets and lesson narratives. Initially, I used *lesson review sheets* with the aim of determining the distribution of dimensions during each lesson. The proportions of time that Anna spent in the various activity structures and the social organizations gave an overview of how the teaching was organized, which enabled comparisons over the seven weeks.

To analyse the *lesson narratives* I started by dividing each of these narratives into segments. Most segments were easily distinguishable, due to Anna's habit of indicating that the class was moving on, for example by saying "Now you'll get to check out these boxes" (Lesson 1) and "It's time to take out your computers" (Lesson 4). To guide the analysis of classroom discourse in each segment, I used the question: *Who determines what is important and correct to talk about in the classroom?* (Mortimer & Scott, 2003). In addition, I scanned the lesson narratives, searching for *principles* (Alexander 2020) suggesting the presence of dialogic teaching (see Table 2). In response to the perceived notion of an increasing gap between the ways of talking and reasoning that are encouraged in schools and those that dominate communication in the wider society, Alexander (2020) designed the dialogic principles to guide teachers who strive towards dialogic teaching which more closely resembles everyday communication. Some examples of such dialogic principles are that communication in class is collective and cumulative which in turn can enable co-construction. Throughout the analysis, I also noted Anna's use of hedges and boosters (Oliveira et al., 2012) which constitute important classroom communication aspects in that they either encourage or discourage co-construction of science knowledge. The overall purpose of the lesson narrative analysis was to investigate whether different teaching practices affected Anna's attempts to offer opportunities for co-construction, and if so in what way.

Table 2. Principles indicative of classroom dialogue (Alexander, 2020)

Dialogic principles Classroom dialogue is:	**Characteristic**
Collective	Teachers and students work together.
Supportive	Students express ideas, without fear of embarrassment or being “wrong”.
Reciprocal	Participants listen and discuss each other’s viewpoints.
Deliberative	Different viewpoints are discussed and evaluated to reach consensus.
Cumulative	Contributions build on previous contributions.
Purposeful	Talk is structured, aiming towards a goal.

It is important to address the concepts of epic and novel science story, as well as NOS, in relation to the data analysis even if these are not systematically analysed. As argued for in the background section of the article, epicization occurs when teachers practice transmissive teaching driven by for example IRE-interactions. Such interactions can be identified for example when boosters are used to evaluate student responses in relation to science content as it is represented in teaching materials or by the teacher. Novelization, on the other hand, can flourish when students are engaged in co-construction of new representations of science. The teacher-student and peer dialogue and interactions that are necessary for co-construction of novel science stories are promoted when hedges are used as scaffolding tools. In addition to the analysis described above, I have therefore considered transmissive, IRE-driven episodes as a sign of epics being reproduced, while dialogic, co-constructive episodes have been viewed as indicative of opportunities for novelized science stories to be created. In addition I have considered the presence of the six NOS attributes in the classroom communication recorded in lesson narratives. For example, if the interactions were supportive and students express ideas without fear of being “wrong” I have considered this as a sign of fostering the NOS attributes tentative, developmental, subjective, and creative (Forbes & Skamp, 2013) among students. Another example is if the communication was collective and the teacher and students appeared to be working together, I have viewed this as a sign of the NOS attribute collaborative (Forbes & Skamp, 2013). During the analytical process I strove to allow the data to ‘speak for itself’ by keeping an open mind when reading the transcripts, and by continuously refining the search for signs, such as types of questions, that indicate epicization, novelization and the presence of NOS attributes in the classroom.

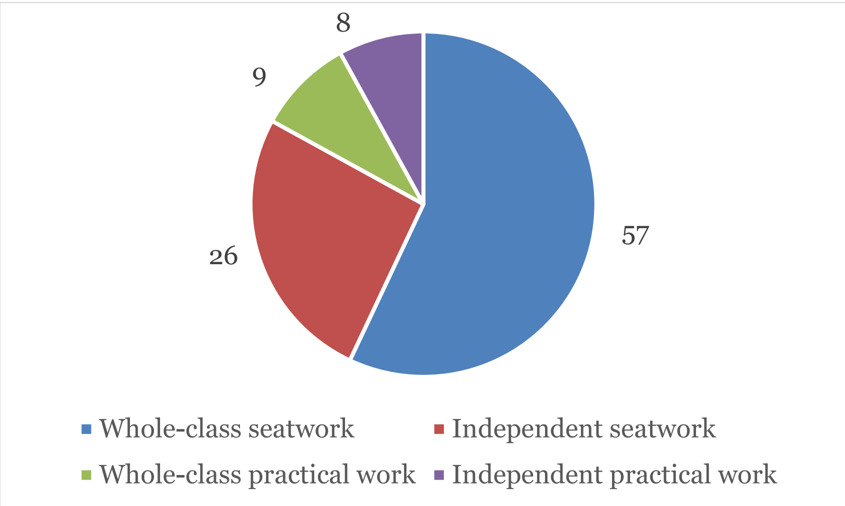
4. Findings

I present the results in two parts starting with the findings from analysing the review sheets to discern the distribution of activity structures. Second, I include empirical examples from the lesson narratives along with analytical notes to illustrate if and how dialogue and student co-construction of novel science stories varied in different ways of organizing the instruction. This is an exploratory case study and although attempts at generalizations drawing from the findings are futile, the data analysis and diagrams showing activity structure distribution offer a rare glimpse into one Swedish upper primary science classroom.

4.1 Distribution of activity structures

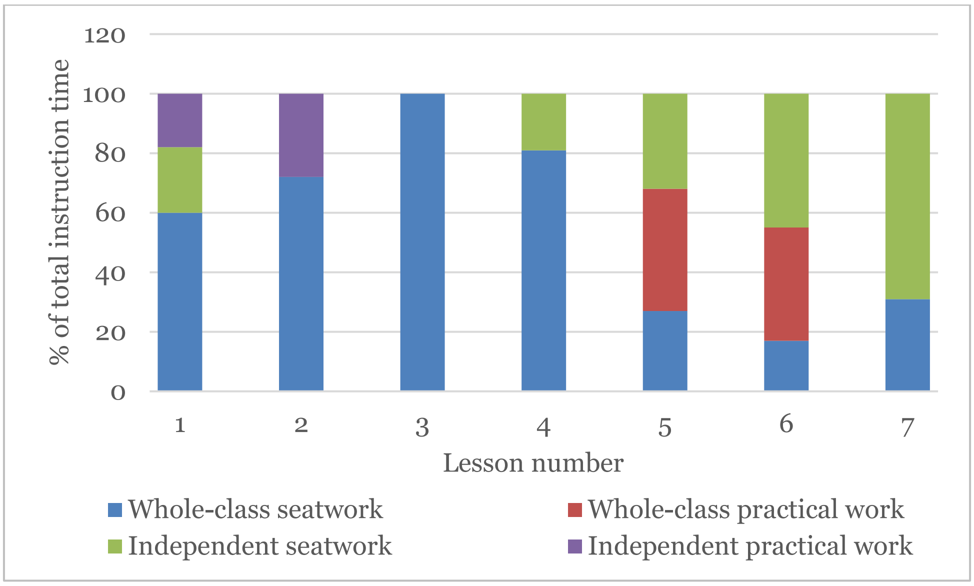
Whole-class seatwork was Anna's most favoured way of teaching, occupying 57 % of the total instruction time (Fig. 1) while independent seatwork was the second most common (26 % of instruction time). Independent seatwork mostly consisted of individual work (65%) where students answered recall questions using their computers. Practical work was less frequent than seatwork and made up 17 % of lesson time, divided almost equally between whole-class and independent work (9 % vs. 8 %).

Figure 1. Distribution of activity structures (% of instruction time)



The distribution of activity structures changed over the 7 weeks (Fig. 2). In the first four lessons, a considerable amount of time – as much as 100 % in Lesson 3 – was devoted to whole-class seatwork. However, in the second half of the period (Lessons 5–7) whole-class seatwork was mostly replaced by independent seatwork. Regarding practical work, Anna engaged the students in independent practical work at the beginning of the subject area (Lessons 1–2), while shifting to whole-class practical work towards the end (Lessons 5–6). Independent practical work consisted of building molecular models and grouping items according to properties and whole-class practical work entailed demonstrations (e.g. burning steel wool and comparing the thermal conductivities of metal and paper).

Figure 2. Distribution of lesson activity structures over the seven weeks



4.2 Empirical examples of communication in different ways of organizing instruction

The results from the second analysis are in the form of three empirical examples from episodes taught in different activity structures (whole-class seatwork, whole-class practical seatwork, and independent practical work). Independent seatwork consisted exclusively of individual work on assignments and was omitted due to its lack of interactions. All three episodes presented here were selected since they displayed potential for Anna to engage students in dialogue and co-construction of novel science stories. They are intended to give a sense of how Anna navigated opportunities for dialogue during different ways of organizing her instruction.

Independent practical work – Building molecular models (Lesson 1). The lesson objective read 'The difference between atom and molecule, the difference between different molecules" and Anna informed the students that they would know these differences after class. In this activity pairs of students were handed a ball-and-stick organic molecular modelling kit. Rather than providing explicit instructions, Anna referred to three magnetic molecular models (water, carbon dioxide, and oxygen) placed on the whiteboard and said, in passing, "you can quickly build one of them".

Nick: How do you make H_2O [/ˌeɪtʃ.tuːˈəʊ/]?
Teaching assistant Maria: Well, then you need, look [pointing to the whiteboard].
Nick: Oh, ok, you need two of those.
Andy: Yeah, and one of those.
Maria: But you were supposed to pick the white ones. Instead of the black ones.
Now you've made two carbon and one oxygen.

7 Nick: I'll make one of those H_2O, I'll make H_2O. I'm done with H_2O. You could
8 make Spiderman DNA or whatever. How to become Spiderman.
9 Simon: Could you build DNA from these?
10 **Maria:** Well, I suppose you could.
11 Nick: There are bent [bond-sticks] too! Look at them, they are bent ones.
12 Simon: Well, they're bendable.
13 Mark: I built a rather cool thing. P-I-S-P-O-L.
14 Nick: I'm gonna make a cool one too.
15 Mark: It's undiscovered.
16 Nick: I'm gonna make a pride* [molecule].

* Nick is referring to the multi-coloured LGBT pride flag.

Analysis. This episode showed the greatest engagement and dialogue among the students observed during all seven lessons. When Anna handed out the kits, feverish activity arose; while the students were building, there were plenty of student-teacher and peer interactions exhibiting dialogic principles and opportunities to learn in an environment promoting a genuine view of NOS. For example, the dialogue was cumulative as speakers built on previous utterances (rows 3, 4, 9, 14). The students also worked collectively and reciprocally when building and reasoning (rows 12-16) with each other and the teachers throughout the activity which lasted for eight minutes. The interactions may have been off-task and/or playful, providing a good starting point for creative discovery and formulation of science in a novel narrative style if they were also scaffolded using hedges. Maria attempts to redirect the students' focus from their exploration by evaluating their work (rows 5-6), but then answers more hedge-like when they start to consider whether the molecular models could be used to build DNA (row 10). In short, there were signs of dialogue and opportunities for co-construction and immersion in NOS attributes in class during this independent practical work segment where students relatively freely expressed their ideas.

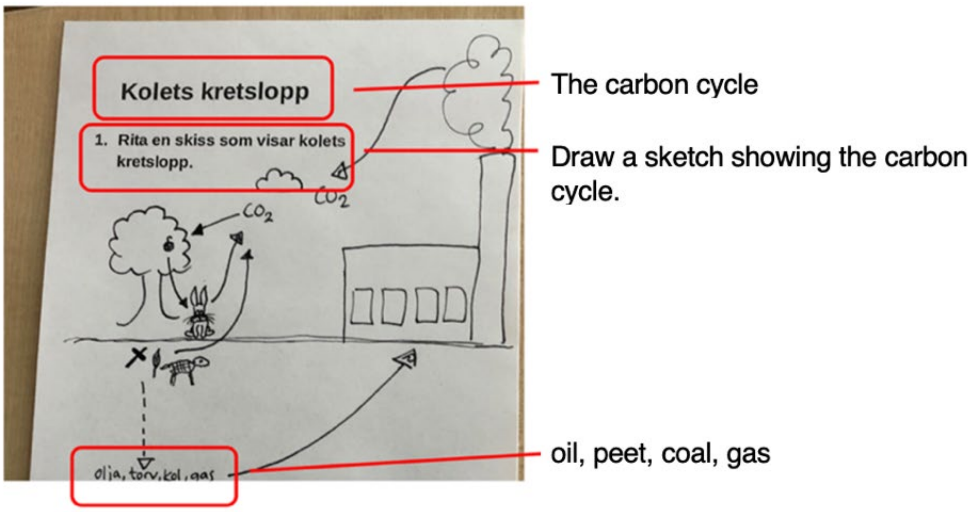
Whole-class seatwork – The carbon cycle (Lesson 3). This empirical example comes from a lesson with an objective stating that students would "Become familiar with the concept of the carbon cycle and know a little about the processes of the carbon cycle". Anna instructed the students to open their textbooks to a certain page and addressed the class:

18 **Anna:** We're going to read about something known as 'The carbon cycle',
19 which we talked a little bit about in fifth Grade, so you might recognize… What is
20 a cycle? We've talked about the water cycle too. How would you describe 'cycle',
21 Simon?
22 Simon: Isn't it like, well, water for example, how, when it becomes solid when it's
23 below zero and gas when it's above zero…
24 **Anna:** Around and around, exactly. It constantly goes around. It changes its state
25 but constantly circulates in something known as a 'cycle'. Circulates around. Now
26 we're going to read about the carbon cycle.

Analysis. Anna initiated with an open-ended question with high cognitive demand, although to some extent based on recall, judging from her cues about it being a repetition. Simon's response (rows 22-23) was phrased as a tentative and reasoning question. His interpretation of the term marked a potential starting point for dialogue and co-construction of a novel science story. However, the only distinct principle indicative of the interaction being dialogic was its apparent purpose to consolidate the meaning of the concept "cycle", which appeared to be represented by the epicized term "around" (rows 24-25). The interaction was neither collective, involving only one voluntary student and the teacher, nor reciprocal, as Anna did not acknowledge, build or ask someone else to elaborate on Simon's answer. Instead, she used the booster "exactly" and accepted his response by rephrasing it as him saying that a cycle is something that goes "around and around" (row 24), even though Simon described a one-way process (rows 22-23). The booster could be interpreted as an attempt to encourage, but also as a sign that Anna was working towards epicization and therefore offered the well-accepted science story of cycles as something that "goes around and around".

In the next episode, which comes from a different segment in the same lesson, Anna distributed a handout (Fig. 3) to the students and announced that the whole class would work on the assignment together. She projected the handout on the whiteboard using the document camera. Holding a pen to start drawing, she addressed the class:

Figure 3. The handout, including Anna's sketch



27 **Anna:** Do you remember what was here on the left? What was it, that absorbed
28 carbon dioxide from the air?
29 Several students: Trees.
30 **Anna:** Trees and plants, that's right. So, let's draw trees over here.
[...]
31 **Anna:** Here I'm going to draw a large, large building. What could that be?

32 Maggie: Humans are building…
33 **Anna:** Yes, it's the humans' building. What could it be, for example?
[Several students mumble answers.]
34 **Anna:** An industry, yes. Some industrial building. And then there is smoke
35 coming out.
36 Nick: Where's the door?
37 **Anna:** And then this industry wants to use, perhaps oil, to heat its' industry for
38 example. Let's draw an arrow from [fossil fuels] up to the industry.

Analysis. The task of sketching the carbon cycle had the potential to spur dialogue and co-construction of several novel science stories. However, instead of allowing students the freedom to develop and draw their story independently and discuss their ideas together, Anna instructed them to copy her drawing which represented an epic science story of the carbon cycle in the form of a fairly complex inscription. The students had already encountered very similar versions of this inscription three times – in the textbook, in a video, and during a monologue by Anna explaining the model – without being invited to unpack or alter the different components. Since Anna listened and responded to several student questions (rows 33-34) the dialogue was collective and supportive to some extent. However, these questions did not revolve around the carbon cycle. While the atmosphere was friendly with partially reciprocal and supportive interactions, and thereby presence of the NOS attributes tentative and collaborative, neither the students nor Anna co-constructed novel science stories since they reproduced an accepted, epic narrative. Anna used boosters such as "that's right" (row 30) to encourage statements in line with the epic. For example, the students' suggestion to draw trees on the left was evaluated as correct, with Anna adding that it could also be other plants although all the inscriptions presented in class displayed trees. Despite open-ended questions, the classroom interactions during whole-class seatwork generally lacked heteroglossia by, although allowing expression of several voices, clearly emphasizing and promoting the epic story transmitted in a unitary language via textbook authors, the teacher, and video narration.

Whole-class practical work – Burning steel wool (Lesson 5). In the segment that this episode stems from Anna had set up steel wool, matches, a metal tray, and a balance scale for a demonstration. After using IRE to establish that steel wool "is a form of iron", she asked the students what they thought would happen as she set fire to the steel wool. One student suggested that it would not burn, and another student offered the opposing guess that it would burn. Anna wrapped up the short interaction by saying "We'll see. Let's try it". The demonstration continued and showed that the lump got heavier after burning and Anna attempted to engage the class in talking about feasible reasons for this.

39 **Anna:** How did it get heavier? Eric?
40 Eric: I don't know. This is a wild guess, but perhaps whatever the fire drops off is
41 heavier than what it removes.

42 **Anna** [doubtful and contemplative]: The fire drops off, is heavier than what it
43 removes? Well, not really, but it’s a good thing that you’re guessing and
44 pondering [...] Or, yes, you’re actually a little right in what you’re saying.
45 You’re thinking completely right. I think you’re getting at what the fire
46 drops off. Something happens as it burns and the reaction from that gets heavier
47 than what goes away. Now I reinterpret your words a little. That’s what you’re
48 thinking? And then it’s exactly like you say.

Analysis. Eric’s response (rows 40-41) seemed to catch Anna a bit off guard, leaving her unsure of how to respond (rows 42-43). The question (row 39) was open-ended with a high cognitive demand and offered an opportunity for collective, supportive, reciprocal and cumulative dialogue. Eric’s response involved reasoning and Anna’s way of responding to some extent displays co-construction of a novel science story as she considers his answer and builds upon it by introducing the term “reaction” (rows 46-47). Although Anna ended the interaction with boosted communication, which in a sense evaluated Eric’s answer and reasoning (rows 43-45, 48), the science story that she offered to represent the demonstrated reaction (rows 45-47) was novel in that it did not contain ‘combustion’ or ‘oxygen’, as would be expected if it were a true epic.

5. Discussion

This study aimed to contribute knowledge about how different ways of organizing classroom teaching practices affected a teacher’s opportunities to engage upper primary students in co-construction of novel science stories. I acknowledge that the presented findings stem from a single-case study and since it offers a snapshot of one classroom, one teacher, and one topic, its generalizability is limited. Nevertheless, by applying the concepts of epic and novel science stories (van Eijck & Roth, 2013) the results feature a new perspective on co-construction of knowledge in upper primary school science class, which could be interesting for other studies in similar areas, as well as for teachers and teacher educators.

The main finding of the study is that, despite engaging in a diversity of activity structures on the topic “Substances around us”, Anna and her students rarely co-constructed novel science stories in class (cf. van Eijck & Roth, 2013). It is important to point out that I am not suggesting that science teaching should always aim to involve students in co-construction of novel science stories. As previously mentioned, epicization serves an important purpose in science communication and education and it is therefore important that students are given insights into the usefulness of an epic narrative style for clear and effective science communication. In accordance with Mortimer and Scott (2003), I do however suggest that efficient science teaching is dependent on a variety of teacher- and student-centred activities, as well as a mix of interactive and non-interactive teaching. While the lessons observed in this study were varied in terms of different topics, organization and learning objectives stated at the beginning of each lesson, the analysis revealed that both teaching material and teaching practices were strongly characterized by epic science stories. The epicization was promoted by an extensive use of established science representations such as molecular structure models and well-spread inscriptions like the image of the carbon cycle (Clough & Olson, 2004). NOS attributes that portray science as tentative, developmental, subjective, creative, and collaborative (cf. Forbes & Skamp, 2013) were somewhat lacking. Anna frequently asked open-ended questions which are known to be useful for promoting co-construction (Menninga et al., 2022). However, the use of boosters rather than hedges to evaluate answers limited the engagement of students in a collective and reciprocal dialogue which could promote a more truthful image of NOS. To some extent, Anna's communication lacked the hedges that are useful to scaffold students' continued reasoning. The questions appeared to serve as prompts to activate students' talk, rather than as an encouragement for sharing and comparing perceptions as a basis for building novel science stories. In this classroom, science was often presented as a set of irrefutable truths discovered by scientists in linear and well-conceived processes (c.f. Bensaude-Vincent, 2006; Grobstein, 2005) and communication tended to build upon boosted communication and IRE-interactions related to previously narrated science 'facts' (Oliveira et al., 2012). Therefore, students were not offered opportunities to become familiar with science and scientific work as subjective and tentative, or science facts as 'only' a summary of current observations composed by communities of regular people working as scientists (Grobstein, 2005; Sutton, 1992). While lessons varied in terms of different teaching contexts, and Anna made efforts to invite different voices in the classroom, the habit of boosting student responses resulted in the science story repeatedly being communicated in a somewhat unitary language using an epic narrative style (cf. van Eijck & Roth, 2013). One conclusion drawn from this finding is that, although Anna took great care ensuring a diversity of activities and teaching materials, she paid less attention to how these variations could be used to support students' co-construction of novel science stories and familiarization with NOS attributes such as tentativeness, subjectivity, creativity, and collaboration. According to the Swedish curriculum students should learn about NOS and yet factual knowledge, narrated as epic science stories, is prioritized and promoted in the classroom regardless of activities, content and organization of teaching context. There is an important lesson to be learned here. In a previous interview study, upper primary school teachers talked about science as a fun subject, while struggling to describe their thoughts on the purpose and practices of classroom communication (Varg et al., 2022). Anna's efforts to mix different activity structures and teaching resources could be viewed as an attempt to make science more fun or at least less monotonous. For me, as an observer, lessons certainly appeared to be varied, at first. However, the finding that most teaching segments promoted epic science stories leads me to suggest that teachers need encouragement and support in developing teaching practices which increase students' engagement in co-construction of novel science stories. One aggravating circumstance is that the lesson objectives observed in this study were often formulated as factual content that the students were expected to learn. In a previous article, reporting findings from the same case study, the difficulty of transforming other objectives than the learning of science ‘facts’ became apparent both through interviews with Anna and analysis of planning documents (Varg, 2023). The tensions between teaching for co-construction and authoritative curricular goals, pointed out by Clarà (2021), implies that an important part of teacher professional development is to include time for teachers to review, discuss and collaborate on subject syllabi in depth. This could improve the transformation process of for example vaguely formulated NOS attributes into rewarding classroom teaching.

The study reported in this article suggests that an epicized image of science is being conveyed and utilized in Anna’s primary school classroom and this could complicate both her and the students’ understanding of science and NOS. The findings from the observed science classroom mirrors what van Eijck and Roth (2013) communicated about the high prevalence of epic science stories in science textbooks. Are the results from this case study surprising? Perhaps, since research has suggested the importance of students’ co-construction of science knowledge and understanding of NOS for several decades. Perhaps not, since research has repeatedly observed transmissive teaching practices and epicization in science class, especially in the case of secondary school (e.g., Tytler, 2010). Assuming that teachers, like most non-scientists, accept and adopt epic science stories with all their entailments for the understanding of NOS including the view of science as objective, exact, and most likely true (Galili, 2019), it is not surprising to find the same view being conveyed in this upper primary classroom. Nevertheless, the results are discouraging and highlight the need to offer and inspire primary science teachers to collaborate in professional development efforts emphasizing the importance of dialogue and a more truthful view of NOS. One option to create such professional development efforts which increase the student-centredness in class focuses on increasing teacher awareness of the social aspects of their questioning (Oliveira, 2010). If teachers are able to increase students’ engagement in co-construction of novel science stories, this would promote the development of creativity, critical thinking, and a more open-minded view of NOS among future generations.

Research ethics

Institutional review board statement

The institutional research ethics board review was not needed for this research. Read more about the ethical review guidelines applied in Finland.

Informed consent statement

Informed consent was obtained from all research participants and in the case of the students, who were under the age of 15, their parents signed the consent form.

Data availability statement

Data is available and can be accessed by contacting the author.

Conflicts of Interest

The authors declare no conflicts of interest.

Appendix A

Lesson review protocol

Material: 2 Digital Voice Recorders, 1 cellular phone (for audio recording)

Date: ________________________
*Duration of lesson:*________________________

Starting time Dimens-ion	13.00		13.05		13.10		13.15		13.20		13.25		13.30		13.35		13.40		13.45
P																			
PS																			
AF																			
AS																			
(SO)																			
PAF																			
Learning environment:																			

Key
P:Phase (Si = science instruction, So = science organisation, N = no science content)

PS:Public speech

AF:Activity function (New content AFN, repetition AFR)

AS:Activity structure (Whole class seatwork, ASWS, whole class practical, ASWP, independent seatwork, ASIS, independent work practical, ASIP)

SO:Social organisation (Independent, SOI, pair, SOP, group, SOG, other, SO)

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