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Language Games and Meaning as Used in Student Encounters with Scientific Literacy Test Items

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(Author copy, last version)
Abstract

Previous research in science education has suggested that difficulties among students learning science relate to challenges in framing its discourse. This article examines the role that language plays in a scientific literacy test for which everyday life is an augmented aspect. Video-recorded data was collected in four ninth-grade science classes in a Swedish compulsory school as small groups of students discussed and collaboratively solved PISA science test items. The theoretical framework assumes sociocultural perspectives as well as that of Wittgenstein’s later works on language. The study involves an analysis of students’ meaning making of specific words that occur in the test and the various language games to which these words contribute. Specifically, we analyzed the students’ use of four different words: reference, constant, pattern, and factor. We found that the students use these words in everyday or mathematical language games; for example, understanding the word “pattern” as a mathematical regularity rather than a result of a scientific experiment. The results were analyzed in relation to the specific illustrations and wording that contextualize the items. We argue that a crucial part of being scientifically literate is privileging science content over other possible disciplines and contexts and ignoring the everyday perspective.

Introduction

Scientific literacy may strongly require that the science community convey its knowledge to the public; however, competing visions (Roberts, 2011) of the concept have been put forward with different foci or intentions on science instruction and education. The two visions generally have been described as contrasting perspectives on science education, one mainly highlighting the traditional products and processes of science itself, and the other highlighting the everyday situations in which scientific components or content are integrated. During the last decade, scientific literacy also has been promoted under the Organization for Economic Cooperation and Development (OECD) as an essential part of the global assessment Programme for International
Student Assessment, PISA (OECD, 2012). In addition to various existing accounts and visions of scientific literacy, OECD has given the concept a specific PISA definition. Understanding science’s contribution to society is central in this definition and conceptual knowledge about and of science constitutes an important cornerstone in the assessment framework (OECD, 2012, p. 99).

The PISA literacy perspective implies that assessment tasks or items are “placed” in situations regarded as “part of the student’s world” (OECD, 2012, p. 102), which means the items are, “framed in situations of general life and not limited to life in school” (ibid). From this viewpoint, the presumed everyday lives of students become an augmented aspect of the PISA scientific literacy test. On the other hand, “everyday life” is a comprehensive domain of situations, and several studies (for example, Serder & Jakobsson, 2014) assert that bringing this aspect into knowledge assessments increases their complexity. In addition, Andrée (2007) argues that everyday life science problem-solving actually may enhance student difficulties. The barrier consists of distinguishing the relevant scientific aspects from the everyday aspects; that is, to interpret the task as a scientific problem. Schoultz, Säljö, and Wyndhamn, (2001a), explore students’ interpretations and understandings of some science assessment items (TIMSS) by asking them to identify the relevant scientific content in order to solve the problems. The results suggest that the students’ performance strongly depends on their everyday understanding of the situation as a whole, rather than exclusively on their conceptual scientific knowledge. In addition, the authors conclude that low performance might be the result of the items’ communicative format and the contextualization of science in everyday life. These conclusions are in line with Olsen, Turmo and Lie’s study (2001) that reworded and reformatted test questions from a TIMSS survey to explore subsequent changes in students’ answers. The results indicate that even small changes in the item wording and/or the item formal may have a substantial influence on the response pattern (p. 417).

However, some questions related to these conclusions pertain to problems in students’ meaning making that actually occur when the scientific content is contextualized in presumed general life situations (as in PISA) and to what extent the identified problems are related to the specific
formulation of the item. In order to approach these kinds of questions, we let students in this study collaboratively solve some PISA science literacy items. In these situations, the students’ negotiations about the meanings of words, concepts, and expressions frequently occurred and have thus been the focus of our study. The analysis is influenced by Wittgenstein’s later framework (1953/1997) of *language games* from the perspective of how it has been used in other, similar studies in science education (e.g. Wickman & Östman, 2002; Wickman, 2004). According to this framework, words get their *meaning as use*, which is interconnected to and inseparable from the situated context and the *function* of words and expressions. We propose that this type of analysis is fruitful for broadening our interpretation of the PISA assessment results as well as for expanding our understanding of students’ meaning making in the science classroom. In addition, it implies exploring the premises of the OECD such that science knowledge can be assessed with items framed by “situations of general life and not limited to life in school” (OECD, 2012, p. 102).

**The “Three-Language Problem” and hybrid discourses**

According to Yore and Treagust (2006), science learners are confronted with a “three-language problem” as they move among home, school, and science languages. The problem, above all, relates to various words of these languages connoting different meanings in different contexts with which students often are unconscious of or unfamiliar. According to the authors, science students must learn to distinguish between these different languages, the different meanings of words and terms used in instruction, and the significance of applying them correctly in appropriate contexts. We perceive these three languages as different and discursive ways of talking that teachers and students are to be aware of and socialized within. However, science, home, or instructional discourses are not exclusive or totally separable languages. In Gee’s account (1999), different kinds of discourses exist and operate at different levels of our lives—societal, institutional, or group. Kelly (2011) describes these various discourses as different “ways of using language in social contexts” (p. 62), and Östman (1998) as, “a systematic process of exclusion and inclusion of words, regarding what to
say and what not to say, how it should be said and how it should not” (p. 55). In this light, the discourses of science become specific choices of words, grammar, idioms, and metaphors, and ways of excluding common elements of everyday life (Lemke, 1990, p. 130).

As highlighted in several studies (e.g., Kambrelis, 2001; Kambrelis & Wehunt, 2012), the languages in science classrooms are often heterogeneous and used both in parallel and in combinations. This implies that meanings of words and concepts from different discourses are constantly being negotiated and situated meanings established. Several scholars have stressed this hybrid (Bakhtin, 1981; Linell, 2009) or heteroglossical (Bakhtin, 1981; Mäkitalo, Jakobsson, & Säljö, 2009) character of learning spaces in science education. Tan and colleagues (Tan, Barton, Turner & Gutiérrez, 2012) argue that an important way of empowering science education is to make these hybrid spaces explicit to students, which implies merging their everyday worlds with the languages of science. Other studies (Hanrahan, 2006; Wallace, 2004; Kambrelis & Wehunt, 2012) consciously use hybridity as a means of developing science teaching practices. For example, Hanrahan (2006) explores how successful teachers use hybrid discourse in order to include all their students, while Kambrelis and Wehunt (2012) highlight how creative “linguistic practices” in classrooms, defined as hybrid discourse practices, produce synergies for science learning. Further, Wallace (2004) argues that hybrid meanings are results of teacher-student negotiations in the “Third Space” (Bhabha, 1994) concerning the meaning of scientific concepts. Wallace (2004) describes the Third Space as an “abstraction of a space/time location in which neither the speaker’s meaning nor the listener’s meaning is the ‘correct’ meaning” (p. 908). The aim of the instruction is instead related to mutual co-construction of interpretations and an “elimination of cultural hegemony in communication” (ibid).

For Mäkitalo, Jakobsson, and Säljö (2009), who studied students’ learning about global warming within an SSI project, the notion of heteroglossia (Bakhtin, 1981) was the basis for analyzing hybrid discourse complexity in heterogeneous learning contexts. Above all, the students’ problem was related to the “heteroglossic properties” (Mäkitalo, Jakobsson & Säljö, 2009, p. 11) of
the discourse; that is, students had difficulties with words that connote differently depending on the discourse in which they operate, which caused confusion among the students. The premises of words in hybrid discourses were often unclear or unfamiliar to the students.

In addition, several unintentional conflations of the meaning of scientific terms used in science classrooms also are possible, which for instance may occur when science teachers use terms in ways that differ from how they are used in scientific practice. For example, a study of science student teachers’ use of language (Gyllenpalm & Wickman, 2011) indicated that student teachers tended to use the term “experiment” to denote what would be referred to as a “laboratory task” rather than a scientific experiment. Gyllenpalm and Wickman assert that this use of the term contrasts with its function in scientific research. Tentatively, this suggests that some scientific terms might have different meanings in science instructional discourse than in academic science.

**The meanings of words in Bakhtin’s heteroglossia**

According to the Russian literary scholar Bakhtin (1981), words gain their meaning and significance in different social languages. As mentioned, an illustration of this phenomenon is the use of the word “experiment” used in instructional discourse in the sense of a “laboratory task” instead of a “design to test an hypothesis” as in scientific practice (Gyllenpalm & Wickman, 2011). Heteroglossia represents Bakhtin’s way of upholding the tension between continuously varying uses of words and terms and multiple (and sometimes rivaling) ways of talking about the same topical domain in different discourses (Linell, 2009). Rommetveit (1974) suggests that words in this way have *meaning potentials*; that is, a “range of possible meanings” (Lemke, 1995, p. 42) that depend on their use in different contexts and on how they are perceived from different social, cultural, and historical perspectives. In line with Bakhtin and Rommetveit, Linell suggests that the meanings of words are accomplished in interaction with others and with contexts (2009). This implies that in situations of heteroglossia, meaning is not given, but is, as mentioned, accomplished in interaction. This view of meaning differs from that of language as a fixed code for transmitting ready-made
meanings (Linell, 2009). Further, Linell views discourse as embedded within contexts, which in turn are potential rather than given or objective. Different actors in a concrete situation bring different assumptions and experiences, all of which influence whether a potential context (and discourse) is actualized.

According to Bakhtin, some forms of languages are univocal, and aim to transmit information without any loss or distortion of information. However, even “authoritative speech genres” (Bakhtin, 1981) do leave space for interpretation; therefore, for instance, different judgments are possible as they originate from one and the same statutory text. In this sense, written surveys such as PISA tests may be regarded as a kind of authoritative speech genre, produced in what Linell (2009) refers to as a “monologizing practice” (p. 173), which aims to reproduce language univocally. Therefore, from a Bakhtinian perspective, it is impossible to produce a written test (such as PISA or TIMSS surveys) without using a univocal text, which in turn makes interactional accomplished meanings in contexts by definition impossible per se. This paradox becomes even more explicit in surveys of students’ scientific literacy in everyday contexts. We return to this issue in the discussion section.

**Language games and meaning as use**

One possibility to enhance the understanding of students’ use of different languages in different discourses is to use Wittgenstein’s *language game* metaphor (1953/1997, §7). This implies to focusing on the actual situations in which students use words because they have something to say to one another, rather than limiting the attention to the objects about which they are speaking. By using the term language games, Wittgenstein asserts that speaking language is part of an activity or form of life. In these situations, we are so accustomed to operating with words that we are not aware of the complexity of what is involved in doing this. In this view, language is perceived as being interwoven with ways of acting, and the connections between words, utterances, expressions, and meaning are not simply found in theory, but in the activity itself. That is, words are not just words:
they are interconnected in specific language games where they have specific connotations and definitions; as Wittgenstein puts it, they have a “family of meanings” (§65–67). Accordingly, meaning becomes more a process, understood and defined as the use of a word in language (§43). For instance, a moral concept like “dignity” in a specific context cannot be fully understood through the encyclopedic synonyms alone (Nordenstam, 1993). To capture its full meaning, the synonym must be complemented with a description of how the word is used in that specific culture, within that specific group of people, and at that specific historical time; that is, in the specific language game. Expanding meaning from the level of single words or sentences towards what they are producing in the conversation implies that the emphasis of student talk analysis must be more on the interpretation of words in relation to their function. However, for Wittgenstein (§11), the function of language and words goes beyond the simplified image of language as only a tool for transmitting thoughts and implies that discourse in conversation and text can serve a multiplicity of functions or purposes. The function of a word in a student conversation may be tied up with what the word “used to do” in other contexts. This means that its function may be in contrast to its meaning as use, which is its situated meaning. In this way, Wittgenstein’s notion of function may be distinguished from his notion of meaning as use, which, in an analytic perspective, makes it possible to explore how students use the relation between them.

Several researchers in the field of science education have used Wittgenstein’s later works especially in order to develop methodological approaches and to interpret student interaction (e.g., Lundegård & Hamza 2013; Lidar, Almqvist, Östman, 2010; Rudsberg, Öhman & Östman, 2013; Ault & Dodick, 2010). Lundqvist, Almqvist, and Östman (2009) analyze how students transform their use of words in specific educational situations to interpret how epistemology permeates the actions taking place in the classroom. Additionally, they use the Wittgensteinian concept of stand fast as a means of analyzing students’ meaning making, that is, their negotiations and actions. According to the authors, the notion highlights situations, “when things stand fast for the participants in practices, in encounters with other people and with the physical world, the way to act is obvious” (p.
That is, standing fast means that the use of the word, or the situated meaning of it, is obvious and therefore, no further negotiations are taking place.

**The study**

The scope of the PISA assessment has sometimes been compared with the framework of socio-scientific issues (SSI; for example, see Sadler & Zeidler, 2009). Given PISA’s explicit intention to assess student knowledge of and about science *in situations of general life* (OECD, 2012) there may be reasons for such a comparison. In SSI problem solving, multiple learning objective perspectives are often deliberatively brought into the context (Kolstø, 2001), which implies that scientific literacy in the PISA framework at least seems to be inspired by and to some extent is similar to socio-scientific issues. Yet, according to Mäkitalo et al. (2009), working with SSI in science education means intentionally “inviting heteroglossia” (p. 9), which implies that students, “are faced with a challenging task of identifying genres and of relating what is expressed in each of these genres to the others in manners that are contextually relevant” (p. 23). Also Ideland, Malmberg, and Winberg (2011, p. 1855) describe SSI situations as challenges of “discursive collisions” and conclude that blending discourses, as when mixing potential scientific and everyday contexts, invokes framing problems.

In relation to these educational challenges, we intend to analyze how and in what ways students in small groups collaboratively approach and solve tasks that are selected from released items in PISA surveys (until 2009). The main purpose is to understand what discursive aspects that are crucial or problematic for approaching test questions that invoke situations in which everyday life is stressed. The main research questions in this study are:

- Which *language games* do students enter in their negotiations about the meanings of the items?
- Which *meanings as use* and which *functions* emerge in students’ problem-solving activities
when they collaboratively solve PISA items?

Methodology

Setting and participants

The data construction in this study took place at a teacher education partner school in a semi-rural, small commuter town located in south Sweden. Three teachers agreed to make their classes available for the project, which resulted in 71 ninth-graders (same age group as the PISA surveys) from four science classes being divided into teacher-constructed groups of between three and four students (aiming for a discussion-friendly climate). In total, 21 groups were formed. The participants amounted to half of their cohort at this particular school. According to available national statistics (www.siris.skolverket.se), those students’ mean final grades in Science by the end of the school year were just at the Swedish average. For the study, the students worked collaboratively in group activity rooms with selected PISA items during one science lesson (45–60 minutes), while their work was video- and audio-recorded (in total, 16 hours of recorded data). In short, they were asked to discuss how they could solve the PISA tasks and then to agree on one written answer per group. The students and their teachers were presented with the videotaped material retrospectively. The items used for the study were tried out in a pilot study in order to ensure that they triggered student conversations. Together with the Swedish and Danish national PISA teams, these items were selected out of the publicly released PISA Science units (https://nces.ed.gov/surveys/pisa/pdf/items2_science.pdf). The items had been used in all the PISA assessments in 2000, 2003, and 2006, and fairly reflected the remaining non-released items of the PISA assessment. We strived to cover as many PISA science aspects as possible (that is, the various PISA-scale science competencies and proficiency levels). As a result of the pilot study, we selected three released PISA units, comprising 11 unique items: Acid rain [S485], Greenhouse [S114], and Sunscreens [S447]. According to the Swedish PISA report (Skolverket, 2007, p. 42) the scientific literacy knowledge assessed by PISA corresponded well with the Swedish curriculum at the time.
Methodological considerations and the analytic procedure

The students took part in what could be described as a collaborative school science activity, although the project was set up for research purposes. We wish to stress that this study neither can nor intends to speak about students’ abilities or knowledge in terms of individual, mental constructs (compare Koretz, 2008). Instead, we see the individual participants as contributing to existing and operating discourses that become observable in action (Wertsch, 1998; Jakobsson, Mäkitalo, & Säljö, 2009). We decided upon documenting via video a group setting without any adults, thus rendering the students’ own discussions and interpretations of the task explicit (e.g. Schoultz et al., 2001a; 2001b).

The research questions were operationalized and analyzed in three distinct, but interrelated phases. In the first phase, all students’ negotiations concerning the premises for the tasks to solve were identified and transcribed. This means that the focus in this phase was directed towards the students’ meaning making and negotiations. This phase was inspired by the framework of Practical Epistemological Analysis (Wickman & Östman, 2002; Wickman, 2004) which uses the analytic concept of gaps for the tension identified when people in interaction encounter situations of dubitation. In our study, gaps are defined as the tension – or empty space (observable as either awaiting silence or negotiation) – that occurs when there are different ways to understand a task and causes the students to negotiate words and meanings in order to explore and create a shared platform or common premises (Mäkitalo, Jakobsson and Säljö, 2009). Thus, gaps were used as a tool for identifying all such situations in the material.

The second phase consisted of using the gaps found to identify which specific words and concepts of the PISA tasks were negotiated in the 21 groups. In this phase, about 20 different words and concepts from students’ discussions were identified as frequent in at least two groups. For instance, the words “absorb”, “oxides”, “marble chips”, “distilled”, “vinegar”, (include this) “step” (of the experiment), “constant”, “factor”, “pattern”, “reference”, “substance”, and “support” (a
(conclusion), were identified in this phase.

In the third phase, the analytic focus was directed on what students’ utterances produced in the specific situations. This phase of further reducing the data used the framework of Wittgenstein’s language games (§7) and the analytic concept of stand fast (Wickman, 2004). Here, we analyzed the meaning as use (§43) of words, understood as the established, situated meaning of a word in a specific group. Thus, one specific word, such as “factor”, could have different meanings as use in different groups. Thereby, the words also produced different functions. This means that we, in the third phase, strived to understand how meanings were created as relations between meaning as use of the words and their previous function in other contexts, according to experiences brought up in the discussions. Ultimately, four words and concepts that caused the most intense negotiations in the groups remained: the Swedish words for “constant”, “reference”, “factor” and “pattern” (that is, konstant, referens, faktor, mönster).

We want to stress the possibility that words in different national languages (such as Swedish or English), might connote both the same and different meanings in the sense that the interpretations (or, to use Wittgenstein, meaning as use and functions) of single words possible in Swedish might not exactly correspond to those in English, and vice versa. However, PISA, as an international assessment movement, is translated into a large number of languages (compare OECD, 2009), which also may be a reason for addressing this issue in an international publication. Additionally, we have narrowed the presentation of our analysis of those four words to include excerpts from three of the 21 groups as particularly accessible for this article format. The reported material is limited for the same reason to two of the three used units of the PISA test (Sunscreens and Greenhouse): In the transcript legend, found at the end of the article and elaborated from Furberg (2009), we have distinguished the students’ own statements from their reading aloud from the test by reproducing the “reading aloud utterances” in Courier New font. The students themselves suggested the students’ pseudonyms.
Results

The first two examples aim to illustrate how the students, while working collaboratively, negotiated and made meaning of three terms (“reference”, “factor”, and “pattern”) that occur in the PISA test unit *Sunscreens*. The unit consisted of one page of introductory text and illustrations followed by four multiple-choice questions in which the last also included an open-ended question. All together, the text, pictures, and questions constitute a kind of story about “science-used-in-real-life,” which we call the backstory.

The *Sunscreens* backstory concerns the fictional students Mimi and Dean who were to investigate the effectiveness of four different sunscreen products (S1, S2, S3, and S4). According to the backstory, two other substances – zinc oxide (ZnO) and mineral oil (M) – were also available in this investigation. (Zinc oxide blocks sunlight, but mineral oil does not.) The text describes that Mimi and Dean conducted their experiment by placing drops of the sunscreen products on light-sensitive paper beside drops of mineral oil and zinc oxide (see Figure 1).

![Figure 1. Illustration in backstory text of the PISA unit *Sunscreens*.

The text describes that sunscreen products have a Sun Protection Factor (SPF) that shows how well...
each product absorbs ultraviolet radiation from sunlight; note that the verb “absorb” and the noun “factor” become important in our results.

The reported episodes concern two different test questions from the *Sunscreens* unit. Initially, the students were working with one of the multiple-choice questions, Question 2, in which they were asked to decide which of four statements best described the role of mineral oil and zinc oxide in the experiment (Figure 2). Therefore, the students had to figure out that mineral oil and zinc oxide were used as controls in this fictional experiment, or in the language of this test question, “references” (answer “D”).

![Figure 2. Sunscreens Question 2.](image)

**Words and concepts in interaction with experiences of everyday context**

In the excerpt below, three students, John, Paul, and George, are discussing Question 2 and are negotiating different possible meanings of the words in the task. Here, the discussion was about the meaning of the words “factor” and “reference” that occur in different combinations in the four response-options reproduced in Figure 2.

<p>| | | |</p>
<table>
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<tbody>
<tr>
<td>1.</td>
<td>John</td>
<td>but a factor is like (.). I mean, how can you explain factor? <em>(looking at George and Paul)</em> = no probably it’s like (.). e:h (.). mm (.). which one was absorbing?</td>
</tr>
<tr>
<td>2.</td>
<td>George</td>
<td>wasn’t it the zinc oxide that absorbed and the mineral oil that let all through?</td>
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<td></td>
<td></td>
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<tr>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td>3.</td>
<td>Paul</td>
<td>Nods</td>
</tr>
<tr>
<td>4.</td>
<td>John <em>(leans his head down for a second)</em> eh how to (. ) reference substance – is it the opposite? <em>(gesticulates with his hands to the right and to the left)</em> I mean reference isn’t it?</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Paul</td>
<td>reference is the opposite yes = or not?</td>
</tr>
<tr>
<td>6.</td>
<td>John</td>
<td>reference in a company is a kind of a contact person</td>
</tr>
<tr>
<td>7.</td>
<td>George <em>(pointing at the text)</em> but in that case the mineral oil is the reference substance and the zinc oxide is the factor being tested</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>John</td>
<td>mm</td>
</tr>
</tbody>
</table>
| 9. | George | so then it is “C”

*[^C states: Mineral oil is a reference substance and zinc oxide is a factor being tested.]|

| 10. | John | but = “C” = it can – (. ) both aren’t- but = it could be ”A” as well (. ) both could be factors *(leans towards George and gesticulates).*

*[^A states: Mineral oil and zinc oxide are both factors being tested.]* |
| 11. | George | yes but do you- (. ) mineral oil = lets everything through = so why would one test it in sun protection then? |
| 12. |   |   |
| 13. | Paul | that would be “C” |
| 14. | John | scratches his forehead (. ) yes |
| 15. | George | that would be good for showing how it gets with no protection at all = in that case |
| 16. | Paul | mm |

14
In this episode, George, Paul, and John oscillate between the information given in the backstory text (such as mineral oil that let all [sun light] through; turn 2) and references to previous experiences that were mediated by this task (such as zinc oxide = for God sake = is for rubbing your nose with when you are sunning yourself. That white cream; turn 19). The group’s negotiation serves to define the meaning as use by relating the terms “factor” and “reference”: What is a “factor” compared with a “reference”? How are these two words related to the different chemical or physical properties mentioned in the text (such as “block sunlight,” “absorb,” and so on)?

In the introduction to the Sunscreens unit, the word “factor” appears only in the composite term “Sun Protection Factor,” which is described as something that sunscreens “have” and which “absorbs the ultraviolet component of sunlight.” Here, some new relationships between the terms are established: a) between “factor” and “absorbing”; and b) between “zinc oxide” and “absorb”. The first relationship is established when John says, but a factor is like (.) I mean how can you explain factor? […] which one was absorbing? (1), in which he relates the meaning as use of “factor” to the

<table>
<thead>
<tr>
<th>Turn</th>
<th>Speaker</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.</td>
<td>John</td>
<td>yes exactly = (attempts to write something on the answer sheet) yes it has to be “C” (.) because the mineral oil has to be a reference substance [Mineral oil is a reference substance and zinc oxide is a factor being tested]</td>
</tr>
<tr>
<td>17.</td>
<td>George</td>
<td>yes exactly</td>
</tr>
<tr>
<td>18.</td>
<td>John</td>
<td>because it lets all through</td>
</tr>
<tr>
<td>19.</td>
<td>George</td>
<td>zinc oxide = for God sake = is for rubbing your nose with when you are sunning yourself (.) that white cream- hell it looks disgusting Moves his hands back and forth</td>
</tr>
<tr>
<td>20.</td>
<td>John</td>
<td>Yes has finished writing the answer</td>
</tr>
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*Excerpt 1. Group X [00:13:00 – 00:16:00] Sunscreens Question 2.*
substance that “was absorbing”. Thereafter, George checks the text (2) and asserts that *zinc oxide absorbed [the light]*. The information given in his text is that “sunscreen products with high Sun Protection Factor (SPF) absorb more of the ultraviolet radiation component of the sunlight” and that “zinc oxide almost completely blocks sunlight.” This indicates that George draws the conclusion that the absorbing substance is the zinc oxide – the relationship he established in turn 2. During the whole episode, these established meanings were never renegotiated or contradicted: zinc oxide absorbs sunlight and it is “a factor.” Thus, this established relationship seems to stand fast (Wickman & Östman, 2002).

This specific relationship between “factor” and “zinc oxide,” in the sense that zinc oxide actually is considered a “factor”, also was observed in several other groups in this study. In a Swedish-speaking context, this is perhaps not very remarkable. One of the everyday life terms used for SPFs in Swedish is literally “sun factor” (*solfaktor*) or just simply “factor.” Therefore, the *language game* (Wittgenstein, 1953/1997) in which the three students are reasoning may be connected to the actions and events of everyday life in which “factors” denote sunscreen products. In addition, the term “factor” (in “Sun Protection Factor”) originally had a mathematical connotation, representing the increase in the amount of time that protected skin could be in the sun without burning. However, in this test question, the term “factor” represents the different conditions to be scientifically tested, that is, the experimental variable. Thus, we have identified at least three different possible *meanings as use* of the word “factor”. We argue that the problem for the students is not exclusively their understanding of the fictive experiment *per se* (or its design), which is the competency to be tested; rather, it is that the word “factor,” which is used in the text as if it were a specific term, has different meanings in different language games. That is, the word “factor” may have a multiplicity of Wittgensteinian *functions*.

After the relationship between “factor” and “zinc oxide” has been established, the students begin to discuss the meaning of “mineral oil” and to establish its properties. In turn 2, George attempts to define it as *mineral oil that let all through?* (while pointing somewhere on his test sheet).
Next, Paul nods to agree (3) and John seems to use this information to try to make meaning out of the different options (Figure 2). He suggests *reference substance – is it the opposite?* (4), something that Paul immediately approves (5). There are several possibilities for perceiving “reference substance” as opposite. One, zinc oxide and mineral oil have opposite qualities among their properties, something described in the backstory text (one lets sunlight through and the other blocks it). Moreover, in this test question the different options could be perceived as inverted versions of each other (Figure 2). When zinc oxide and mineral oil semantically are set as antonyms as in this text, the impression could be that the substances actually are opposed to each other. According to John and Paul, zinc oxide and mineral oil must be either a “factor” or a “reference substance.”

In his next statement, John attempts to give the term “reference” a meaning, that draws on a parallel to everyday life: “reference” as a kind of contact person (5) that one must refer to when applying for a job. However, George picks up the first possibility in which the substances are viewed as opposites (as put forth by John in turn 4), and suggests, *but in that case the mineral oil is the reference substance and the zinc oxide is the factor being tested* (7). His proposition corresponds to option “C” in the test (suggested in turn 9, 13, and 17). In fact, only at this point in their discussion zinc oxide as factor and mineral oil as reference are compared as opposites. However, this is the meaning as use that eventually stands fast. The negotiation continues as John proposes that both [zinc oxide and mineral oil] could be factors? (10), but George rejects this suggestion as inconsistent with the given information: *mineral oil = lets everything through. So why would one test it in sun protection then?* (11). Here, he asserts that there is no point in testing a substance that does not block sunlight, and therefore mineral oil cannot be a factor to be tested. The meaning as use of “factors” is substances that block sunlight, a meaning that then stands fast (Wickman & Östman, 2002).

The way in which the students discuss the words and relate them to each other is different from what we would interpret as the intention in the item. Still, in this excerpt, the intended meaning of the term “reference substance” as a control in the experiment is actually reached at one point. When George asks why mineral oil would be tested (11), he orient attention toward the fictive experiment
itself and what it might be like. When he states, *that would be good for showing how it [the result of the experiment] gets with no protection at all* (15), he stresses the actual role of the mineral oil (as a control), from which John concludes that *the mineral oil has to be a reference substance* (17). Therefore, while connecting the fictive result “no protection at all” (15) with “a reference substance” (17), John establishes a meaning as use of “reference” that is valuable and correct in this test. However, the meaning of a “factor” is still used as in the language game in which “factors” are not scientific variables, but a synonym for sun creams. This might explain why the group selects “C” in which zinc oxide is a “factor” – *that white cream* (18), and not the correct answer (“D”).

**Words and concepts in interaction with illustrations and graphs**

In the second example, students worked with another test question from the PISA unit *Sunscreens*, Question 5 (Figure 3). This test question has two parts: First the test-takers are to select the correct option from four pictures representing the fictive results of the sunscreens experiment (described earlier), and second, explain their choice. As described, the experiment investigates the effectiveness of four different sunscreen products, S1, S2, S3, and S4 (represented as circles in Figure 3). The backstory explains that drops of the products are placed on light-sensitive paper, which is then placed in the sun. The backstory text also states that mineral oil (M) and zinc oxide (ZnO) are used in the experiment (circles “M” and “ZnO” in Figure 3). Question 5 explains how the light-sensitive paper behaves when exposed to sunlight, and asks: “Which one of these diagrams shows a pattern that might occur? Explain why you chose it.”
Figure 3. Illustration in Sunscreens Question 5.

In short, test-takers must think upon what happens when different sunscreens (“Sun Protection Factors”) are placed in the sun and conclude that they let through different amounts of light, which causes the light-sensitive paper to change to different colors. The correct answer is “A” because the mineral oil (M) allows all sunlight through, turning the paper white (represented as a white circle marked “M”), while the area with zinc oxide (ZnO) remains dark (represented as a dark grey circle marked “ZnO”).

In the following example, four students – Alice, Blondie, Greta, and Viola – discuss Question 5 and negotiate the word “pattern.”

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8.</td>
<td>Alice</td>
<td>so it’s supposed to be a pattern?</td>
</tr>
<tr>
<td>9.</td>
<td>Blondie</td>
<td>inaudible</td>
</tr>
<tr>
<td>10.</td>
<td>Greta</td>
<td>but how can a pattern occur? [seems puzzled]</td>
</tr>
<tr>
<td>11.</td>
<td></td>
<td>(.)</td>
</tr>
<tr>
<td>12.</td>
<td>Blondie</td>
<td>here is no pattern whispering</td>
</tr>
<tr>
<td>13.</td>
<td>Alice</td>
<td>yes</td>
</tr>
<tr>
<td>14.</td>
<td>Blondie</td>
<td>no</td>
</tr>
<tr>
<td>15.</td>
<td>Alice</td>
<td>somewhere</td>
</tr>
<tr>
<td>16.</td>
<td>Blondie</td>
<td>no</td>
</tr>
<tr>
<td>17.</td>
<td>Greta</td>
<td>I don’t even understand the question</td>
</tr>
<tr>
<td>18.</td>
<td>Blondie</td>
<td>neither do I (yawning) (. ) Yes here is a pattern =</td>
</tr>
<tr>
<td>19.</td>
<td>Alice</td>
<td>“A”? [option “A”]</td>
</tr>
<tr>
<td>20.</td>
<td>Blondie</td>
<td>here it is light here it is dark here it is light here it is dark here it is light here it is dark (pointing at alternative A on her diagram) here it is like = dark light light dark light dark [option B] here it is light light dark light dark light [option C] here it is light light dark light light = so here it is like light dark light dark light dark dark so it is a pattern [option A]</td>
</tr>
<tr>
<td>21.</td>
<td>Alice</td>
<td>is it “A” or? [option “A”]</td>
</tr>
<tr>
<td>22.</td>
<td>Greta</td>
<td>maybe it’s supposed to be a more = &lt;well-formulated&gt; explanation waving her arms</td>
</tr>
<tr>
<td>23.</td>
<td>Blondie</td>
<td>giggling</td>
</tr>
<tr>
<td>24.</td>
<td>Viola</td>
<td>here’s a pattern too (pointing at Blondie’s diagram in a diagonal pattern) [showing something on alternative B]</td>
</tr>
<tr>
<td>25.</td>
<td>Blondie</td>
<td>NO</td>
</tr>
<tr>
<td>26.</td>
<td>Greta</td>
<td>(laughing) OF COURSE it is – there are two diff - NO there aren’t</td>
</tr>
<tr>
<td>27.</td>
<td>Blondie</td>
<td>they do not have the same colors (looking at Greta) [pointing at “C”]</td>
</tr>
<tr>
<td>28.</td>
<td>Greta</td>
<td>NO they HAVEN’T</td>
</tr>
<tr>
<td>29.</td>
<td>Viola</td>
<td>neither do these [the pattern in “A”]</td>
</tr>
<tr>
<td>30.</td>
<td>Blondie</td>
<td>no but is is light light light dark dark dark</td>
</tr>
<tr>
<td>31.</td>
<td>Greta</td>
<td>(laughing) oh damn</td>
</tr>
<tr>
<td>32.</td>
<td>Alice</td>
<td>but we think it’s ”A” or what?</td>
</tr>
<tr>
<td>33.</td>
<td>Greta</td>
<td>YES but what kind of an explanation do we have? ( . ) because here it’s dark and there it’s light? [sarcastic intonation]</td>
</tr>
</tbody>
</table>
Excerpt 2. Group P [22:11-26:00]; Sunscreens Question 5.

In this example, the word “pattern” is uttered by all four girls and on five occasions (10, 12, 18, 24, 36); however, at no point do the students suggest different possible meanings or interpretations of the word. Rather, the meaning as use of the word stands fast (Wickman & Östman, 2002). What are the possible consequences for how the group understands this task? For instance, in reaction to Greta as she asks but how can a pattern occur? (10), Blondie replies that here is no pattern (12), without questioning what kind of “pattern” this concerns. However, using the word “pattern” in this way seems to be a problem because Greta asserts that she cannot find an explanation for a “pattern” to happen (22, 33); asking how can a pattern occur? (10).

According to both the Swedish as well as the English encyclopedias, the word pattern applies to a variety of functions or meanings. As background for further analysis, we refer to those, thereby illuminating the heteroglossic (Bakhtin, 1981) complexity of this word. The word pattern may represent:

a) a model – an example for reproduction or imitation (for production but also for behavior) or anything designed or fashioned as a model for something to be made. As such, the pattern is the original;

b) an example that is positively valued (a good example);

c) the word for a regular arrangement of lines or figures on a surface, such as a geometrical pattern;

d) decorative designs such as textile fabrics or wallpapers;
e) an arrangement of numbers in mathematical patterns, in which the recurrence of certain intervals forms the pattern;

f) a combination of qualities or tendencies forming a consistent or characteristic arrangement;

g) an underlying structure of a complex system that might not be apparent at first glance.

This is not to argue that all of these functions are potential in the specific situation we are analyzing. However, we argue that these different functions might be used within different language games and that both Greta and Blondie use the word “pattern” within a mathematical language game. In this excerpt, Greta continues to ask for an explanation for why a pattern would occur, while Blondie presents a pattern that she has found (20). Blondie’s statement includes the words “light” and “dark” and describes the order of light and dark circles in the illustration (Figure 3). She systematically goes through all of the four options to establish that the option demonstrating a pattern is the one that is light dark light dark light dark (20), which corresponds to every second color dark every second color light in the picture (Fig. 3). Our interpretation is that Blondie has searched for a symmetry or regularity. This suggests a meaning as use corresponding to a geometrical pattern, such as a regular arrangement of lines or figures on a surface (compare c) in the encyclopedic enumeration above). Therefore, we analyze her use of pattern as within a mathematical language game. At this point, Alice suggests choosing option “A” (19, 21), in which the circles on top are lighter than those at the bottom (thus a type of “pattern” consisting of dark and light circles), which is the answer that the group eventually provides in their written answer.

However, the students have apparent difficulties using “pattern” in this way. Yet, its function as a mathematical attribute, rather than as an underlying structure of a scientific experiment (as intended), continues to stand fast during this episode. We suggest that for this group, the meaning as use of the word “pattern”, in a Wittgensteinian sense, is actually never negotiated. ; To understand why this is, we need to analyze the situation in its context as a whole. As stressed by Linell (2009), contexts are potential rather than given or objective, in the sense that it is what individuals bring into the situation that eventually determines what kind of a context becomes the relevant. Thus, the
question is what it is in this task that makes it a potential mathematical language game. It is possible, as stressed previously, that our interpretation is colored by the national language the students use. However, it is also possible that the specific presentation of the task mediates a mathematical context. For instance, the word “diagram”, preceding the word “pattern” in the item (Fig. 3), is a word for which the function is often to be a mathematical representation of statistical data (something the translators seem to have overlooked). In addition, the word “diagram” can denote a graph and, therefore, has a specific meaning in a mathematical language game.

According to the Swedish curriculum, patterns and diagrams (graphs) are both concepts to be learned in mathematics education in secondary school, and therefore, also occur in mathematics textbooks for 15-year-olds in Sweden. The point is that staying in the mathematical language game (and for multiple reasons) actually seems to prevent students from acting within other language games in which this family of words (Wittgenstein, 1953/1997) has other meanings. As a consequence, the students have difficulty finding an explanation for the pattern to occur (the second part of Question 5). Mathematically, patterns can occur without being structured from underlying systems or theories; that is, they can exist without simple explanations.

Let us revisit the problem solving of Greta, Viola, Blondie, and Alice. They abandon the item for a while before returning to it. In between the presented episodes, the group reads aloud from the backstory text about the chemical and physical properties of mineral oil and zinc oxide. Before completing their work with Question 5, the following exchange takes place:

<p>| | | |</p>
<table>
<thead>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>54.</td>
<td>Greta</td>
<td>now we just have to find something on number five (. ) OH MY GOD</td>
</tr>
<tr>
<td>55.</td>
<td>Blondie</td>
<td>otherwise we just take my suggestion that there is darker and lighter</td>
</tr>
<tr>
<td>56.</td>
<td>Greta</td>
<td>That sounds so completely = gone (. )</td>
</tr>
<tr>
<td>57.</td>
<td>Blondie</td>
<td>so don’t write it</td>
</tr>
<tr>
<td>58.</td>
<td>Greta</td>
<td>or just write the THERE IS no pattern ’cause a pattern can’t occur because there are different factors</td>
</tr>
</tbody>
</table>
Excerpt 3. Group P [22:11-26:00]; Sunscreens Question 5

Following Greta (backwards) through these episodes, we see that she tightly focuses on finding an explanation (33, 22, 10) just as the task requires them to do (Figure 3). Yet, as we stressed earlier, mathematically, patterns can exist without explanations, which means that finding a pattern of this kind on a disc of sun creams does not give an obvious meaning. If Blondie and Greta are acting within a mathematical language game, we better understand the problem in finding an explanation. As Greta stresses, the only pattern found is the one that that Blondie suggests (54), which Greta says sounds so completely gone (56).

In her final utterance on this matter, Greta appears to abandon the idea that a “pattern” can exist. She adds that a pattern can’t occur ’cause there are different factors (58). As used here, “different factors” appear to make a pattern impossible. Why so? Could it be that the word “factor” is understood in an everyday Swedish context as a sun protection product? That possible confusion is discussed previously in this article. If Greta’s uttered problem with how such a pattern could occur has its origin in her understanding of “factor” as denoting sun protection cream – why would a geometrical pattern occur in that situation? Finally, we would like to address the illustration of this item: a rectangular picture with light and dark circles. Undoubtedly, circles and rectangles as mediational devices may have mathematical connotations and can thus be seen as representations – as well as a picture showing experimental results. In line with our argument regarding the use of the word “diagram,” we suggest that the geometric figures occurring in this particular context may actualize a mathematical as well as a scientific language game.

This leads us to conclude that the meaning as use of the word “pattern” is within a mathematical language game. However, we are aware that alternative interpretations of this situation are possible.
“Constant” as meaning in a graph

To broaden the perspective, we turn to results from the *Greenhouse* unit (Figures 4 and 5). This unit begins with a short introduction to the scientific meaning of the greenhouse effect, and introduces the reader to the fictional students André and Jeanne, who meet in a library. According to the backstory, André and Jeanne discuss two graphs (Figure 4) demonstrating carbon dioxide emissions and earth temperature variations during the 20th century. André concludes from the graphs that an increase in temperature is caused by carbon emissions, while Jeanne doubts this simple causality.

![Figure 4. Illustration in the Greenhouse unit.](image-url)
Three different questions are posed in the *Greenhouse* unit. For the first two, the graphs (Figure 4) are to be used. The tasks are to find evidence – and counterevidence – to André’s conclusion that the increase in the average Earth atmosphere temperature is because of increases in carbon dioxide emissions. The graphs co-vary most of the period, but at some points do not increase or decrease simultaneously. However, for the last question, called Question 5, (see Figure 5), students must put aside the graphs and reason about the premises for comparing them.

*Figure 5. Greenhouse, Question 5.*

The “factors” (in the sense of scientific variables) that should be mentioned in a written response to Question 5 might be sun radiation or volcanic eruptions; for example. To be valid in this context, the variables should be “constant,” unchanging.

In the following example, a third group from the study—Larry, Xavier, and Stig—discusses Question 5. The excerpt begins when the group reengages in problem solving after a short break in which they have discussed whether the greenhouse effect really is the problem that researchers claim.

<table>
<thead>
<tr>
<th>32.</th>
<th>Larry</th>
<th>so what are we going to answer on the last question?</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.</td>
<td>Xavier</td>
<td><em>(yawns)</em> I don’t know - Before accepting this conclusion you must be sure that other factors that could influence the greenhouse effect are constant (.) but none of these two [plots] are constant = then there would have been an increase all the time and there isn’t because here is a v-shape</td>
</tr>
</tbody>
</table>

*Points at the graphs*
As in the first two examples, the established meanings are situated in a very specific context of experiences, illustrations, and wording, and within the story describing the tasks. How can we understand how such meanings are developing in the students’ interactions and how they are intertwined?

The meaning of this task as it unfolds in this particular exchange become tightly interconnected with the word “constant,” which is found in the second-to-last sentence of the test question (*you must be sure that other factors that could influence the greenhouse effect are constant; see Figure 5*).
Xavier immediately takes up this word (33) while he engages in the problem solving. Still, at a point in this discussion, the focus changes from negotiating the meaning of the word “constant” as related to the graphs (33–43) to a reconsideration of the task (44–49) and a subordination of the graphs’ significance. To respond to this question, the students actually must disengage with the graphs.

Let us start the analysis from the utterance in which the problem solving begins: *but no one of these two [plots] are constant* - (33). Here, “constant” gets related to these two – that is, the two graphs/plots. Clearly, the students are actually referring to the graphs because Xavier continues to talk about an *increase* and a *v-shape* (33), alluding to the shape of the curve in the graphs. In this excerpt as well, we assert the meaning of use of the word “constant” to be within a mathematical language game in which “graphs” as well as “constants” (and “factors”) have certain meanings. We recall that according to Wittgenstein (1953/1997), the actions that can be undertaken are framed within the language game entered. In this example, Xavier, Stig, and Larry immediately frame their actions to the study of the graphs.

In the first part of this excerpt (33–43), the meaning of the word “constant” as used is related to 1) the graphs (in turns, 33, 35, 38–41) and 2) the idea of linearity (as in 39 and 40): *here you have a straight line* (40). It is less certain, but yet possible that the students also relate “constant” to the word “factor,” as in turn 37 in which Xavier tries to understand what is being asked, and states, *other factors that can be constant*. How can we understand why the students enter this language game at all? In previous sections, we suggested that some words (“factor” and “diagram”) have particular connotations that might be specific to a Swedish context (sun creams, statistical representations). Therefore, these connotations in Swedish are within their *meaning potential* (Rommetveit, 1974) and are related to what the words *used to do* (Wittgenstein, 1953/1997, §11). Although there seem to be no meaning potentials tied to the national language regarding the word “constant,” we suggest that the local/national institutional context is important. In a Swedish school context, graphs are important mathematical tools. In the ninth-year mathematics textbooks for this school, graphs are
particularly used in the context of mathematical functions \( y = mx + c \). In this context, “factors” are used as the numbers to be multiplied with “x” \((m)\), and “constants” are the numbers that designate the intersection of the function with the y axis \((c)\). In addition, students at this level of education in Sweden almost invariably learn to draw graphs for first-degree equations (that is, they draw straight lines). Therefore, we suggest that it is useful to analyze these students’ conversations within this specific language game.

In turn 38, Stig says, *they are constant or they aren’t a straight line = they are either going up and they are going down*; he thereby claims the interruptions of the curves, their increase and decrease, to be related to the meaning of the word “constant.” In the next three statements, Xavier (39), Stig (40), and Larry (41) stay in this mathematical language game, in which the meaning as use of “factors” and “constants” are tied to drawing actions and interpreting graph shape. The relation they try to establish is that “constant” means a straight line.

After a short interruption of the discussion (43), the unproductiveness of this use of the word becomes apparent. In turn 44, Larry says, *so we are supposed to kind of give such a factor* and then suggests that to be a *factor that can change = that has something to do with the greenhouse effect*. He then is relating “factor” to things that affect the greenhouse effect, and the group’s written answer names a factor that could contribute to the greenhouse effect (“as cutting down the rainforest”), which is in line with Larry’s final interpretation (48).

This example demonstrates how the difficulty students have in solving a problem may not be essentially their lack of scientific knowledge, but rather the context in which the problem is posed and the different language games in play. To use Linell (2009) the context actualized in a situation depends on the expectations, experiences, and demands of the person situated in the context. Therefore, it is questionable whether a specific, univocal contextual understanding really can be transmitted or proposed through the text, without offering interfering contexts for interpretation. Within the communicative format of a test situation, students are required to disconnect from other interfering knowledge and experiences. To some extent, test-takers must put themselves in the place
of the test constructer. Here, it is not until turn 45 that Stig states his uncertainty about the intended meaning of the question as a test question.

What about the context for Larry, Xavier, and Stig? In the first 10 analyzed actions of this example (33–42), the group discusses the problem within the language game that we must suppose appears the most salient to them from their perspective, which turned out to be the mathematical one. As we see it, it is characteristic of students to be learners of many different disciplines simultaneously, something that is rarely addressed in either assessment research or science education research. This means that in contrast to, for instance, the test constructer, for students in school there is not one single language game in which contexts, words and tasks get meaning, but several.

Discussion – What does it take to be scientific literate?

The assessment of students’ knowledge and skills in PISA has been problematized in a number of research studies. Examples from the field are PISA’s impact on policy work (Grek, 2009; Sellar & Lingard, 2013), the effects of language translation in such international, standardized testing (Arffman, 2010; Puchhammer, 2007), and its validity when it comes to actually measuring specific, scientific competencies (Lau, 2009). According to the OECD, the PISA framework was established explicitly to assess students’ scientific literacy in an everyday context, or as “part of the student’s world,” and not exclusively “limited to life in school” (OECD, 2012, p. 102). Previous research has addressed the problem of assuming a common “everyday life” for 15-year-olds over the globe (Bonderup Dohn, 2007; Sjøberg, 2007). However, in this article, we argue that these conditions implicate specific student ability when it comes to understanding and using hybrid contexts and languages (Hanrahan, 2006; Wallace, 2004; Kambrelis & Wehunt, 2012) and a capacity to break with singular discourses.

Several research studies have pointed out that the implicit use of hybridity may be particularly difficult for science education students who are faced with the challenging task of identifying
different discourses and genres to relate them to different meanings and use them in manners that are contextually relevant and productive (Mäkitalo et al., 2009). However, the question is what the added complexity of an everyday context brings to students’ meaning-making in a classroom perspective and what impact it may have on the general validity of PISA test items. The latter issue may be intrinsically related to what kind of knowledge domains are actually assessed and what kind of conclusions about the students’ scientific knowledge it is possible to draw.

To come closer to these issues, we have analyzed students’ meaning-making in small-group problem solving, focusing on collaborative negotiations about the PISA items and the use of specific words in the items. In order to operationalize these comprehensive issues, we have chosen to use Wittgenstein’s (1953/1997) language game metaphor, where the use of words is perceived and interpreted as interwoven with ways of acting. The analysis has mainly focused on the meaning of words as used in students’ discussions in relation to their function. According to Wittgenstein (1953/1997), the function of a word or sentence is tied up with what it “used to do” (for example, in other discourses and contexts), which may be in contrast to their meaning as use, (- the situated meaning). We argue that this framework can contribute when it comes to analyzing and understanding students’ meaning making in hybrid discourses in science education. Furthermore, it may provide knowledge about the challenges that are actualized by large-scale assessments of scientific literacy in everyday contexts.

In our study, the meaning of the words “reference”, “factor”, “pattern”, and “constant” (included in PISA units Greenhouse, Sunscreens, and Acid Rain) were frequently negotiated by the students. The word pattern occurs in the test background text, representing the result of a scientific experiment. However, several students framed their discussions within a mathematical language game – in which a pattern was given mathematical properties of regularity and symmetry – rather than a scientific one, which resulted in a situation where they actually never discussed the scientific content in a science language game. Consequently, the students’ search for mathematical patterns represented the majority of the time spent working on the problem. Similar examples were found in
students’ meaning-making about the words “factor” and “constant”. For the word “factor”, we identified at least three possible meanings as use that resulted in misunderstandings of the premises of the problem solving situation and confusion among the students. Rather than seeking to understand the fictive experiment as a scientific problem (the competency tested), the negotiation of the word “factor” was in focus. Situations in which the students actually entered the intended scientific language games in this study were relatively rare.

As stressed earlier, large-scale assessments of scientific literacy in everyday contexts seem to pose a paradox: on one hand, the words and terms used in assessment items have to be univocal (Bakhtin, 1981) to transfer a universal meaning; on the other, they need to introduce situations of everyday-life contexts, in which meanings necessarily have to be accomplished in interaction (Linell, 2009). The included everyday-life situation and the increased hybridity seem to invite more possible discourses and contexts, which in turn result in more complex, compound problem-solving situations. These results align with Mäkitalo et al. (2009), which describe students’ problems of framing as an aspect of the complexity in heterogeneous discourses of socio-scientific issues.

The problem we have touched upon is whether some of the students actually enter the language game in which their competencies are being tested, such as their understanding of scientific reasoning or usage of scientific concepts and methods. The formulations of the test items, and their embeddedness in everyday contexts, risks making the scientific content hidden, or invisible, for the students. In our analysis, we observe how the students are often caught in negotiations about the meaning of words that are not typically scientific. Another way of viewing this problem is to consider the very understanding of the test questions as part of the assessed scientific literacy and to interpret the students’ understanding of hybrid discourses. The question is whether the PISA results are communicated from such a perspective. In their reports, the OECD presents the PISA results as representations of the students’ actual knowledge of and about science and as their ability to apply this knowledge to real-life situations. We assert that “applying” knowledge is constrained here to frame the tasks within fictive examples, which seems to cause obvious problems in the students’
meaning making. Thereby, the PISA assessment of knowledge risks becoming an assessment of how students understand and address specific words and contexts used in these fictive examples. This does not imply that we deny the value of applying scientific knowledge in situations outside school. Instead, we want to stress the limitations that arise when assessing students’ scientific literacy in this way. Thus, from a PISA assessment perspective, being scientifically literate seems to demand privileging the scientific content over other disciplines and contexts, and ignoring the everyday contexts. This also suggests that being scientifically literate involves interpreting PISA items, and the words included, exclusively within a scientific discourse.

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**Transcription legend**

[ ] Text in two square brackets represents clarifying information

= Indicates the break and subsequent continuation of a single utterance

? Rising intonation

Underlined: Emphasis in talk

(.) Short pause in the speech

- Single dash in the middle of a word denotes that the speaker interrupts herself

-- Double dash at the end of an utterance indicates that the speaker’s utterance is incomplete

CAPITALS: Loud speak

*Italics* Context descriptions

<text> Indicates that the enclosed speech was delivered more slowly than usual for the speaker

**Courier New**: Students’ reading from the text in the test is typed in Courier New

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References


