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Building a web in science instruction: using multiple resources in a Swedish multilingual middle school class

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ABSTRACT

This study, on the unit measuring time, examines classroom use of different resources and their affordances for students' meaning-making. The data, comprising audio and video recordings, fieldnotes, photographs and student texts, were collected during a lesson in a multilingual Swedish grade 5 classroom (students aged 11–12). In order to analyse the connections between the different resources, such as talking, modelling, using bodily action and practical equipment, reading and writing, and their affordances for meaning-making, we use pedagogical link-making, Dewey's principle of continuity and Halliday's Systemic Functional Linguistics. Findings show that in using these multiple resources, the teacher builds a web by linking various modes of representation, affording the multilingual students several opportunities for making meaning of the science content. Talk holds the prominent position and is linked to the other mediating resources, which in turn are linked to each other in all possible constellations. Science content is hereby mediated and reinforced through the web of multiple resources.

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Introduction

Meaning-making in school science presents major difficulties for students, especially for second language learners and non-mainstream students (Lee 2005; Martin 1999). These students are in need of 'explicit instruction' involving a broad 'range of scaffolding strategies' (Cummins 2015, 275). In Sweden, science is taught in Swedish, which may pose challenges for multilingual students due to gaps in their knowledge of everyday and academic Swedish (Jakobson and Axelsson, 2012). In upper secondary, school students can choose between a university preparatory science programme and a vocational natural resource programme. Statistics on grade 9 students' academic achievement in 2011–2015 show that only 60% of students with foreign background were entitled to continue their studies at upper secondary school in regular programmes (National Agency of Education 2016). The remaining 40% are enrolled in a special programme, Language Introduction, in order to improve their Swedish (corresponding students with Swedish background are enrolled in individually shaped programmes). Furthermore, less than half of all students entering

the university preparatory science programme in upper secondary school have a foreign background. Scholars have proposed explanations for this trend, such as the linguistic demands associated with learning science. Science is taught via the majority language, in this case, Swedish. For multilingual students, this means they learn science and its specialized language, potentially creating distance between the science subject and these students' lives. Research on learning science through a second language has great resemblance to research on learning science in a foreign language in Content and Language Integrated Learning (CLIL) programmes. A key issue for second language teachers as well as CLIL teachers is how to integrate science content and language without emphasising language at the expense of content (Weinburgh et al. 2014).

Learning at school differs from learning outside school, since school content is based on writing with specific conventions and ways of construing reality (Halliday and Martin 1993). Furthermore, new ways of thinking about a phenomenon demand new language resources and vice versa: new ways of using language result in a somewhat different view of the world. When everyday knowledge is constructed, language is often supported by affordances in the environment, such as gestures, demonstrations and physical objects. Schleppegrell (2004) argues that language is the key to understanding and presenting content as well as managing activities in the science classroom. As Lemke (1990, 153, emphasis in original) puts it, 'the mastery of science is mainly a matter of learning how to *talk* science'. Accordingly, science learning can be seen as mediated through language, but also through multimodal representations such as models, graphs and symbolic language (Lemke 1990, 1998; Schleppegrell 2004; Wellington and Osborne 2001). Kress et al. (2001, 14) maintain that different modes of communication 'interact with and contribute to the other', and must be interwoven in the classroom to enhance learning. Furthermore, Scott, Mortimer, and Ametller (2011) argue that pedagogical links need to connect ideas through meaning-making interactions in the science classroom.

It is well known that several modes of representation are used in the science classroom. Axelsson and Danielsson (2012) investigated how the atomic model was represented by blackboard notes and drawings, teacher 'chalk talk' and gestures in multilingual grade 8/9 classrooms without students making links between the various modes. Another study on observing goldfish showed how different resources, such as painting, sculpturing, writing poems or observing and talking, have different consequences for what young children notice (Jakobson and Wickman 2008). A study carried out by Jakobson and Wickman (2015) reported how, through joint activities – observing and rubbing – young children's meaning-making about leaves was promoted, cognitively, aesthetically and normatively about how to act in science class. However, Zhang (2016) argues that there are barely any studies on the use of multimodal representations in multilingual science classes. In her study on grade 6 physics, life and earth science classrooms, the results revealed gaps not only between the multimodal representations used and communication between teacher and student discourse but also between everyday and scientific language.

Wellington and Osborne (2001) maintain that reading and writing are not common activities in science class, but argue for their significance. Yore et al. (2004) emphasise that becoming scientifically literate involves not just being able to critically read scientific texts, but also to evaluate them and learn how to write them. Or, according to Wellington and Osborne (2001, 42), learning to read scientific texts critically is 'a key element of scientific literacy'.

In her study on science acquisition in Swedish grade 5 and 8 classes, af Geijerstam (2006) claims that writing has a peripheral role in science instruction. Instead, emphasis is often on ‘doing’ science which runs the risk of students not gaining access to the genres of science. Likewise, Ødegaard et al. (2014) revealed contingent occurrence of literacy activities (reading, writing, talking) during scientific inquiry with 6- to 11-year-old students in Norway. They stress the importance of regularly embedding literacy activities when young students perform scientific inquiry. This is further supported by Jakobson and Axelsson (2012) who show how young multilingual students (Swedish grade 2) are mainly involved in hands-on activities while reading and writing are overlooked. On the contrary, Howes, Lim, and Campos (2009) claim that literacy activities may prevail over science learning. Furthermore, the various resources used in school science are specialised, which may imply that neither language nor other resources may be familiar to students. In such situations, the resources may constitute a hindrance for learning (Jakobson and Wickman 2008). Consequently, how students are afforded possibilities of science meaning-making depends on the situation and the resources available to them.

As multilingual students vary in terms of academic language proficiency, it is of interest to focus on how multiple resources are used in a multilingual science class. In order to make adequate assessments and provide multilingual students with effective instruction, it is essential for the teacher to identify content language characteristics and use various mediating resources (Bailey 2007; Cummins 2015; Martin 2007; Schleppegrell 2004; Wellington and Osborne, 2001). Thus, in this study, we aim to investigate the resources which also include literacy activities that multilingual middle school students are afforded in a lesson on the revolving of celestial bodies in the unit *Measuring time*.

Theoretical framework

We take our stance in Dewey’s principle of continuity, Halliday’s Systemic Functional Linguistics (SFL) and sociocultural perspectives. Learning is viewed as part of a dynamic process in which meaning is continuously construed in encounters between people as well as between people and the surrounding world. This is in line with Dewey’s (1938/1997) principle of continuity which implies that earlier experiences are reconstructed and transformed in new situations, having consequences on present and future situations. Hence, learning is a continuous and ongoing process with a purpose (Wickman 2006), always taking place (Lave 1996). However, learning might take another direction than intended by, for example, a teacher (Rogoff 1990). Moreover, Scott, Mortimer, and Ametller (2011) emphasise the importance of continuity for learning science at school. Continuity entails making links between different situations on a time scale, such as macro, meso and micro scales. Macro scale refers to experiences during lessons over an extended period of time, micro scale is connected to experiences during the specific lesson, whereas meso scale is related to recent sequences of lessons.

As learning and meaning-making occur in interaction with people and the surrounding environment, teachers and students are equally involved in the meaning-making process through the use of language and multimodal resources (Kress et al. 2001). Accordingly, both teachers and students link new situations to previous ones, which is in line with Dewey’s (1938/1997) principle of continuity. Promoting continuity implies, according to Scott, Mortimer, and Ametller (2011), developing the scientific story and managing/

organising the activities of the classroom. Furthermore, Scott, Mortimer, and Ametller (2011) underscore the significance of supporting knowledge-building in science class. In this study, supporting knowledge-building and promoting continuity are in focus when analysing the role of different resources in science meaning-making.

Language, as formulated in SFL, is systematically organised according to the functions it has to fill and represents grammar as ‘networks of interlocking options’ (Halliday 1985, xiv) rather than as rules. Thus, language is viewed as a system of resources for meaning-making focusing on the linguistic choices people make in different situations. Furthermore, SFL (Halliday 1985) offers a functional grammar meta-language connecting language to meaning. Regarding scientific discourse, there is an overall understanding about its difficulties (Halliday and Martin 1993). Academic knowledge is often solely construed through language, making language carry ‘the whole burden of information’ (Halliday 1999, 85). Furthermore, the choice of resource for meaning-making is viewed as a result of social, cultural and situational aspects, including participants and available multimodal resources. In science education, various multimodal resources, such as written and spoken language, still and moving images, gestures and physical artefacts are used during scientific inquiry and instruction (Kress et al. 2001; Lemke 1998). Lemke (1998) concludes that various multimodal resources need to be used in the science classroom, since each resource can contribute to meaning-making in specific ways, and a certain level of redundancy can be beneficial for learning.

Analytical approach

We use *pedagogical link-making* developed by Scott, Mortimer, and Ametller (2011, 3) to analyse ‘the ways in which teachers and students make connections between ideas in the ongoing meaning-making interactions’ in the science classroom. According to Scott, Mortimer, and Ametller (2011, 13), there are six approaches to supporting knowledge building: everyday and scientific ways of explaining (a), scientific concepts (b), scientific explanations and real-world phenomena (c), modes of representation (d), different scales and levels of explanation (e), and analogous cases (f). However, an important approach to supporting knowledge-building not addressed by Scott, Mortimer, and Ametller (2011) is the contribution of literacy to learning science. In this article, literacy mainly refers to talking, reading and writing and the use of meta-language connected to school science. Therefore, we add a seventh approach: making links between science knowledge and literacy (g). Moreover, continuity is examined by using Dewey’s (1938/1997) principle of continuity and Scott, Mortimer, and Ametller’s (2011) approach to promoting continuity, which is classified in relation to a time scale: macro scale (h), meso scale (i), micro scale (j). The letters a–j refer to the pedagogical links used (Table 1).

Methodology

The data reported in this paper are part of a larger three-year project, ‘Multilingual students’ meaning-making in school biology and physics – an interdisciplinary study on subject and language’. The data comprise 74 hours of video recordings and 178 hours of audio recordings from one grade 5 and one grade 8 class in two multilingual suburban Swedish schools. In addition, digital photos of the classroom environment, textbooks,

Table 1. Pedagogical link-making during the lesson.

	Teacher (t)	Student (s)	Total number
Support knowledge building			
a Everyday and scientific ways of explaining ‘rotating–energy–pulls–gravitation’	3	1	4
b Between scientific concepts	–	–	–
c Scientific explanations and real world phenomena ‘tide... it has to do with the moon and the water, that it recedes’	1	13	14
d Modes of representation ‘the teacher attaches the model of the sun to the whiteboard – a yellow paper semi-circle’	11	1	12
e Different scales and levels of explanation (symbolic or macroscopic) ‘movement–moving–rotating–round–circle’	4	3	7
f Analogical link-making	–	–	–
g Literacy and science knowledge ‘why do you think I’ve made them (cards) red’ ‘participants’	4	7	11
Total number	23	25	48
Promote continuity			
h Macro scale ‘Teacher: And as you know, this has tagged along since grade one’	2	7	9
i Meso scale ‘Do you know something that’s of importance to us in our galaxy influencing us concerning time?... tide’ (building on the previous lesson)	2	2	4
j Micro scale	–	–	–
Total number	4	9	13

worksheets, tests and student notebooks were collected. One aspect behind the selection of the particular grade 5 class (11-/12-year-old students) was the high proportion of multi-lingual students: in the class, 100% of the students were multilingual (likewise, in the school as a whole, 99% of the students were multilingual). A further aspect was the school’s focus on SFL. The participating Swedish teacher was qualified for teaching science in Swedish grades 1–7 (students aged 7–12 years old) and had attended in-service courses following the Swedish version of the STC programme (Science and Technology for Children). Moreover, she was educated in genre pedagogy and SFL, in line with the intention of the larger project.

Data collection

The grade 5 class was visited during an autumn term throughout the science unit *Measuring time*, which lasted four months. Data for this particular study comprise a 70-minute lesson on the revolving of celestial bodies, resulting in 4 hours of audio recordings and 2.5 hours of video recordings. In addition, photos and fieldnotes were collected. Of the 21 students in the class, 16 agreed to participate in the study. Of these, nine were born in Sweden, seven born outside of Sweden and of those two were newly arrived. Most of them reported using two or more languages at home.

The lesson was carried out in half-class groups with 10 students present. Students were involved in whole-group and pair discussions as well as hands-on activities. Student interactions were audio recorded with microphones at their desks comprising four group conversations. Teacher interactions and instructions were audio recorded with a microphone worn by the teacher. In addition, video recordings were made with two cameras, one at the back of the classroom and one focusing on one group of students.

Data analysis

Audio recordings were transcribed and triangulated through data comparison to video recordings, photographs and fieldnotes to secure reliability. The unit of analysis was defined as ‘situated action accompanied by speech’. *Pedagogical link-making* was used for data analyses (Scott, Mortimer, and Ametller 2011), focusing on *knowledge-building support* and *continuity promotion* (c.f. Dewey 1938/1997). During the analyses, instances of link-making were marked according to the categories in Table 1. All links made by the teacher and the students were labelled from a to j and if used by teacher (t) or student (s). For reader clarity, all cited examples are marked in the text according to these labels. In addition, teacher and student actions, such as gestures and reading, are indicated within square brackets in the excerpts.

The study was conducted by following ethical guidelines as stated by the Swedish Research Council (2015).

Findings

During the present lesson, a number of resources were used in addition to speech; in this case models, bodily action, practical equipment and reading and writing. The resources are presented under each heading.

In Table 1, instances of pedagogical links used by teacher and students to support knowledge-building and promote continuity during this lesson are displayed. As for continuity, most links were made on a macro scale by students, and there were no links on a micro scale. To support knowledge-building, most links were made by the teacher through modes of representation, followed by students asking questions about the scientific explanations and real-world phenomena.

Models as a resource

Initially, the teacher recapitulated the previous lesson’s writing task concerning imaginary consequences of not being able to measure time by using clocks. She also connected to earlier discussions on how time was measured, using, for example, sunset, sunrise and tide, that is, links on the meso scale (it). Thereafter, the teacher continued by attaching a two-dimensional model of the sun to the whiteboard:

- (1) Teacher: And as you know, this has tagged along since grade one [laughs, and attaches the model of the sun to the whiteboard – a yellow paper semi-circle]. And this is two-dimensional and it’s, we’ll have to imagine the sun here.

During this sequence, three pedagogical links were made by the teacher: a continuity link on macro scale (ht), previously used in ‘grade one’, a continuity link on meso scale (it), recapitulating the previous lesson, and a link concerning modes of representation (dt) between the real sun and the model of the sun, which in this case was ‘two-dimensional’ and which the students had to ‘imagine’ as the sun. The teacher then attached the two-dimensional model of the moon to the whiteboard and asked about ‘our whereabouts’. One student answered ‘the earth’, confirmed by the teacher:

- (2) Teacher: The earth. We're on the earth [attaches a two-dimensional model of the earth to the whiteboard]. And those [pointing to the sun, the moon, the earth], they are moving in a lot of different ways. And it's the movements of the earth and the moon in relation to the sun that create those concepts of time we've been deciding.

The teacher now made a link between everyday (e.g. sunset and sunrise) and scientific ways of explaining (at) by talking about the revolving of the moon and the earth in relation to the sun, thus 'create[ing] concepts of time'. At this point, Fatima asked about the 'black stick' attached to the model of the earth:

- (3) Fatima: Miss, that black stick, is that an axis?
 (4) Teacher: Yes, the axis of the earth, isn't it? This is so that you can imagine. I think I'm going to fetch a ball and a stick [fetches a paper pulp ball and a stick]. Ball. You can see that it's the earth, can't you?
 (5) Ammar: Yeah.
 (6) Teacher: This is like a make-believe-stick 'cause it's round this. It's sort of in, as the whole earth rotates [shows how the earth is revolving round its axis by rotating the paper pulp ball on the stick]. So, to imagine this we have to think that there's a stick, an axis going through the earth. The axis of the earth is not a stick sticking out. It's an idea. Do you get it?

Fatima's earlier experiences of 'an axis' were reconstructed, that is, a continuity link on macro scale (hs) was made, shown by her question about the 'black stick' (3). The stick as an axis was confirmed by the teacher as something you could 'imagine', 'make-believe', and see as 'an idea' not observable in the real world. Accordingly, the teacher made a link between the axis of the earth and the stick of the model as a representation (dt), simultaneously making links between the model and earth (dt). Like Fatima, the students posed questions or made statements concerning real-world phenomena and scientific explanations (cs). One example is Ammar who wondered:

- (7) Ammar: About this, mm, the earth is rotating round the sun. You know I think...But you know, in the energy of the sun, you know, the energy that pulls things in, is it 'cause of that that the earth rotates round 'cause it, you know, has sort of the gravitation and...
 (8) Teacher: Aha! You're thinking like that! May I return to that 'cause today I thought that we'll start working with the movement itself. How everything is moving in relation to each other. ... What did Ammar say about the movement? Ammar said that the earth is rotating. How? What did he say?
 (9) Muna: It goes round the sun.
 (10) Teacher: Round the sun [draws an arrow on the whiteboard showing the direction of the revolving of the earth round the sun]. Oh, yeah! The earth moves round the sun. Then we've got a movement here. But there are more movements.
 (11) Muna: The moon.
 (12) Teacher: The moon moves.
 (13) Muna: Round the earth.
 (14) Teacher: Do you agree?
 (15) Ammar: Mm.

(16) Teacher: Does the moon move round the earth?

(17) Several: Yeah.

(18) Teacher: Okay. The earth is moving round the sun and the moon moves round the earth [draws an arrow showing the direction of the moon revolving round the earth].

To Ammar it was intelligible that the earth revolves round the sun using the term 'rotating round' (7). However, he was unsure about how this happens and suggested that it is due to 'the energy that pulls things in' and to 'gravitation' (7). Hence, Ammar reconstructed and transformed his earlier experiences of 'energy', 'pulls' and 'gravitation' linking his experiences to a macro scale of continuity (hs) by using everyday and scientific language (as). Up until this point, gravitational forces in relation to planetary movement had not been part of the curriculum, but Ammar might have learned this at home in informal conversations or by watching a TV programme. The teacher neither confirmed his utterance nor raised the topic for discussion. Instead she referred to Ammar's statement that the earth 'rotates round the sun' using the term 'movement' (8). By doing so she made a link to different ways of explaining (et) and expressing 'revolving'. Returning to Ammar's statement that the 'earth is rotating', the teacher asked how this could be and Muna said that the earth 'goes round the sun'. The teacher accentuated Muna's answer by drawing an arrow round the model of the earth showing the revolving, thereby making a link between two modes of representation (dt): Muna's utterance and the drawing. She then asked about more movements and got the answer 'the moon' [moves] 'round the earth' (11–13), and again accentuated the phenomenon by drawing arrows round the moon (16–18).

The links made by the students draw attention to earlier experiences on a macro scale (hs) since this had not been discussed in science class during this unit. Moreover, the students and the teacher made links between science knowledge and literacy (gst) shown by the use of the terms 'rotate' (Swe. *rotera*, *snurra*), 'move', 'movement' and 'goes round' when talking about the revolving. The teacher proceeded by asking about more movements concerning the actual celestial bodies:

(19) Sophia: What is it, the earth moves round the moon.

(20) Teacher: The earth moves round the moon. Hence, the moon goes round the earth and the earth goes round the moon [shows the movements with her arms]. Actually not.

(21) Fatima: It moves round itself. The earth moves round its own axis.

(22) Teacher: Does it?

(23) Fatima: It does rotate by itself. The earth rotates. It does.

(24) Teacher: It does. Are you quite sure?

(25) Fatima: Yes.

(26) Teacher: Do you agree that the earth is rotating round its own axis?

(27) Several: Yeah.

(28) Several: Noo.

(29) Fatima: Yeah, you said that yourself last time, in grade two.

(30) Teacher: [laughs] Did I say that in grade two? Yes, but then it has to be like that, doesn't it? The earth rotates round its own axis [draws two arrows showing the revolving of the earth round its own axis].

Sophia's utterance (19) was rejected by the teacher. By combining Sophia's utterance with the actual revolving of the moon simultaneously showing the movements with her arms (i.e. a link between two modes of representation, gestures and language) (dt, gt), the teacher tried to illustrate the illogical nature of Sophia's statement. Fatima then gave a correct definition, probed by the teacher (22) to which some students agreed and others did not. Fatima, however, insisted that the teacher had said so in grade two, making a link to the macro scale of continuity (hs) (29–30). The teacher laughed, confirmed and drew arrows round the model on the whiteboard showing the revolving of the earth round its axis (dt). The teacher used the word 'moves' as a synonym for revolve, which Sophia picked up. The teacher then chose to use 'goes round', which Fatima adopted, but then changed to 'rotate', illustrated in a drawing by the teacher. Accordingly, there was a link between science knowledge and literacy (gst) through the use of varied language as well as between two modes of representation: talking and drawing (dt).

Although the students were acquainted with the models used, there was a need to emphasise that models are used as representations when talking about phenomena not being possible to grasp in reality. Moreover, the models were amplified by gestures and arrows showing the direction of the revolving when approaching a scientific language. Hence, the use of models was continuous with science meaning-making.

Bodily action as a resource

To further students' meaning-making they were told to enact the earth and the sun, in effect making a link between two modes of representation (dt), bodily action and model:

- (31) Teacher: If I'm the earth. Ali, you can be the sun here. You're the sun. Come a bit closer. I'm the earth and I'm rotating round my own axis [turns round], but simultaneously I rotate round, what?
- (32) Fatima: Round the sun.
- (33) Teacher: Yes! So, as I rotate round myself I simultaneously rotate round the sun [shows with her body]. Do you follow me? Suado! Come! Can you be the earth now? Can you be the sun Naihma? Stand there in the middle. Come! You're the sun. If you're the earth (to Suado), how are you going to move then? You'll move. [Suado moves round her own axis and the sun]. Good! Round your own axis and round the sun. Very good! Thank you! Do you follow me?

In this situation, all students in pairs experienced the revolving of the earth round the sun through bodily action. The activity was successfully performed by the students and afforded still another experience of the revolving of celestial bodies.

Experiencing the revolving of the earth through bodily action is an immediate and palpable activity, incorporated in the students' meaning-making process in this situation. In conformity with the use of models, bodily action was shown to be continuous with learning about the relation between celestial bodies. However, the moon was excluded from this bodily action.

Practical equipment as a resource

When adding the moon the teacher introduced yet another resource: practical equipment including sticks, paper pulp balls and torches. The teacher divided the students into pairs or groups of three and handed out the materials:

- (34) Teacher: Two sticks. So, this is of course the moon [holding a small paper pulp ball on a stick]. You've got an earth. Now, together you're going to try to get this to work. Stand up! [opens her arms up wide]. You, try to act [bringing her arms and fingers together by forming a circle].

In order to illustrate the revolving of the celestial bodies, the students used a small and a big paper pulp ball to represent the moon and earth, respectively. These were attached to a stick (to represent the axis) and the students were given a torch (to represent the sun). During this activity, links between various modes of representation (dt) were made: practical equipment, models, bodily action and oral language. However, the practical equipment caused difficulties, as it was hard to move 'the moon' round 'the earth' when simultaneously moving the earth round on its own 'axis' and round 'the sun'. Instead of moving the practical equipment the students moved their own bodies. The teacher concluded that 'It's hard to get it as it is in reality, isn't it?', revealing awareness of the complexity involved in this specific activity. Consequently, in this situation, using practical equipment caused difficulties for the students in performing the activity. However, the activity, as presenting some links between various modes of representation, might anyway contribute to students' meaning-making, even though it did not fully meet its purpose. However, the activity had the potential to be continuous with learning about the revolving of the celestial bodies.

Reading, writing and using SFL as resources

A pair reading and writing activity was introduced aiming at sentence construction through the use of cut-up sentences, written on cards (Figure 1) concerning the revolving of celestial bodies related to time such as day and night, month and year. This was the very first time the teacher made a connection between the revolving of celestial bodies and units of time. The activity aligned to the general SFL orientation of the school in such a way that all participants were written on red cards, processes on green cards and circumstances on white cards. Furthermore, the teacher directed the students to the red cards comprising different words for units of time while implicitly requesting meta-language:

- (35) Teacher: So, what do all those movements have to do with time? I've prepared some envelopes for you. And inside here there're a lot of words. When you get your envelopes, the first thing you're going to do is to find those cards [shows them]. Day and night, month and year [attaches the cards to the whiteboard]. Why do you think I've made them red?
- (36) Ammar: 'Cause we're going to find words that you can use when measuring time, if it's day and night and a month and a year.
- (37) Teacher: No, it's not 'cause of that they are red.

Figure 1. Students constructing sentences of words written on cards.

(38) Muna: Participants.

(39) Teacher: Participants. Exactly! If I'm going to describe something [makes a fist in front of her body] which processes are very common when you're describing something? Anyone who, if you're going to describe an animal or something like that. What kind of processes are there? Have you forgotten everything? (sighs). But say, describe me [points to herself with her hand].

(40) Ammar: You are very stern.

(41) Teacher: He just says 'you are' [bunches right fist and moves it round]. What kind of process is that?

(42) Muna: Something you are.

(43) Teacher: Something you are. Exactly! 'Are' and 'has' and 'is' are such usual processes when you're going to describe something [makes a fist with her right hand and moves it round]. So you're going to find a lot of 'is'. Your task then will be to sort so that there's a description of what day and night is, what month is and what year is [writes 'is' after the units of time on the whiteboard]. Do you understand the task? (divides the students into pairs).

When Ammar suggested that the words in red were connected to 'measuring time' this was rejected (36–37), because the teacher requested the metalinguistic term for subject according to SFL. Muna gave the redemptive meta-language 'participants' (gs). The

teacher continued along the SFL meta-language strand asking for ‘processes’ involved when ‘describing something’ (gt). The concept ‘process’ was reinforced on three occasions by the same gesture, making a fist with her right hand and moving it round. Muna gave a definition of ‘process’ as ‘something you are’ (gs) and the teacher added more examples of processes in descriptions such as ‘has’ and ‘is’ (43) (Swe. har, finns). The students had prior knowledge of SFL terminology (hs), and some of them grasped the teacher’s request for meta-language in this situation. The teacher thus made an explanation link on a symbolic level (et).

During the activity some questions were raised, implying that the revolving of the celestial bodies in relation to measuring time was still not clear to the students:

(44) Fatima: Day and night is the time it takes for the earth to rotate round the sun.

(45) Teacher: Are you sure? What’s day and night?

(46) Fatima: To rotate round its own axis.

(47) Ali: And month is the time that the earth rotates round its own axis.

Obviously, it was not clear to the students which unit of time was related to which revolving, which was not surprising as the relations between time and the revolving of the celestial bodies had not yet been elaborated on. However, the students made links between science knowledge and literacy (gs) when constructing sentences in line with their perception of various time units for the revolving, not always in line with science proper. Ammar, though, reconstructed and transformed earlier SFL knowledge when forming the sentences:

(48) Ammar: Wait! Have you noticed this? Look! Red color is the participants then. Hmm, and green are the processes then. ‘Cause look! Hmm, the processes are ‘is’, ‘is’, ‘is’. To rotate, that’s that, but the participants are ‘day and night’, ‘month’, ‘year’, ‘moon’, ‘the earth’ and ‘its own axis’. ‘The sun’. But then there were those white ones. I think they are processes of action.

Ammar explicitly uttered the word categorised as a process, ‘is’, and the words categorised as participants (48) (gs). Furthermore, he noticed words written on white cards, suggesting they were ‘processes of action’, in reality circumstances. The activity ended with the students writing down the constructed sentences in the notebook. Concerning ‘month’, three definitions appeared:

(a) Month is the time it takes for the moon to rotate round the earth.

(b) The time it takes for the moon to rotate round the earth is month.

(c) Month is the time it takes for the earth to rotate round the moon.

Sentences (a) and (b) are both linguistically idiomatic and in line with science proper. In (a), the participant is in topic position, while in (b), circumstances are topicalised. The third example, (c), is similar to (a) and linguistically idiomatic, but the content is not in

accordance with science proper. In similar ways, the sentences were constructed when concerning the earth. In contrast to the other resources used (models, bodily action and practical equipment), this activity entails a higher cognitive demand on both language and content. Students were familiar with and supported by the SFL meta-language represented by the colours of the cards and thus succeeded in constructing grammatical sentences in Swedish. However, the time aspects involved in the revolving of celestial bodies had not been introduced earlier leading to insecurity about content.

Accordingly, during this instructional sequence the teacher initiated a reading and writing activity, intended to make links between science knowledge and literacy. However, as science content was new to the students, not all attained continuity between language and content.

Concluding discussion

The findings show that by building a web of multiple resources, the teacher affords the multilingual students an opportunity to make meaning of science content (Figure 2). The resources are linked in a reciprocal and dynamic fashion. In accordance with Lemke's (1990) emphasis on the need to talk science, the figure thus positions speech as the major mediator in science learning during this science lesson (Halliday and Martin 1993; Lemke 1990; Schleppegrell 2004; Säljö 2005).

This multilingual class comprised students with varied proficiency in Swedish which the teacher was well aware of. Therefore, she consequently afforded the students multiple resources when illustrating the same scientific phenomenon. This is in line with Kress et al.

Figure 2. A web of multiple resources.

(2001) and Lemke (1998) who see multiple resources as beneficial in the science classroom. However, different resources could have different consequences for student learning, which is something teachers might want to put to the test (Jakobson and Wickman, 2008, 2015). It is also obvious that different resources present varied demands on language and cognition. Bodily action was an immediate illustration since it is both visual and physical, and possible to perform with limited language output. The use of practical equipment had the potential to promote students' meaning-making due to its visual and physical qualities. However, in the performed context, this resource caused the students practical difficulties and did not fully meet its purpose. The models used in the lesson, on the other hand, filled the purpose of illustrating abstract and non-graspable phenomena. In addition, they were reinforced by gestures and arrows showing the direction of the revolving.

On the one hand, the literacy activity, unlike the other resources, entailed a higher cognitive demand on both language and content. On the other hand, the enacted literacy activity afforded students both an opportunity for negotiation in pairs and extended time for processing (c.f. Halliday and Martin 1993; Schleppegrell 2004). The lingering issue is not that reading and writing activities ought to be a part of the science class (Ødegaard et al. 2014) or a fear that literacy activities may prevail over science learning (Howes, Lim, and Campos 2009).

Instead, we claim, in line with, for example, Wellington and Osborne (2001), that teachers have to treat language, literacy and science content as entangled entities in order to make students aware of how language and literacy are parts of science learning. This is especially important for multilingual students who are simultaneously learning science content and developing a second language.

A web of multiple resources may promote multilingual students' opportunities to make meaning of science content. Focus on the same content, presented through various resources, affords occasions to embrace the subject from different viewpoints. Furthermore, when instruction is in the second language, the pedagogical situation is strongly favoured by a multi-modal approach to instruction, focusing on both everyday and scientific languages. Studies on second language acquisition stress the importance of an early introduction to content as students develop a second language (Jakobson and Axelsson, 2012; Bailey 2007; Cummins 2015; Schleppegrell 2004). Further research will need to address the question of how to balance the focus on content, literacy and language, and how this balance may be supported by educators' use of a web of multiple resources, that is connecting pedagogical links (Scott, Mortimer, and Ametller 2011) when teaching multilingual students.

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