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Exploring coherence and authorship in pedagogical link-making in science

Sami Lehesvuori [a,b] and Jaume Ametller [c]

[a]The Department of Teacher Education, University of Jyvaskyla, Jyvaskyla, Finland; [b]The Department of Science and Technology, University of Johannesburg, Johannesburg, South Africa; [c]The Department of Specific Didactics, University of Girona, Girona, Spain

ABSTRACT

Despite rapid changes in education, science classrooms will remain central forums where fragmented pieces of information are brought together to construct coherent knowledge as concepts and explanatory scientific storylines. There is limited work stressing the importance of the interplay between how content is communicated through pedagogical link-making and the use of communicative approaches. Even less research addresses the role of coherence in this process. In this study, through exploring three cases of teachers teaching the same topic, we will bring forth differences on how links between past and to be learned scientific knowledge are made. We look at how authorship – whether teacher or students make the links – is related to students cognitively and emotionally engaged with the discussion. Besides revealing differences in these aspects, communicational coherence was found manifesting in different levels in the examples. Based on the findings, we discuss the role of communicational coherence and pedagogical link-making in meaningful learning of science.

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Introduction

Teaching and learning are facing challenges due to rapid developments in society. As networked digital technology offers pathways to access and share information, learning environments are expanding outside traditional classrooms. It is important and necessary to open education up to the new opportunities these developments bring about, but classrooms will remain important forums where fragmented pieces of information are brought together to construct coherent knowledge as concepts and explanatory storylines (Staarman & Ametller, 2019). In the case of science education, this knowledge construction takes place at the interplay between science language and connected activities to address information about natural phenomena through scientific practices (Sensevy, Tiberghien, Santini, Laubé, & Griggs, 2008). This is at the core of learning science

CONTACT Sami Lehesvuori sami.lehesvuori@jyu.fi The Department of Teacher Education, University of Jyvaskyla, P.O. Box 35, 40014 Jyvaskyla, Finland; The Department of Science and Technology, University of Johannesburg, P.O. Box 524, Johannesburg 2006, South Africa

through inquiry- or phenomenon-based approaches (FNBE, 2014) including opportunities and activities for scientific modelling and argumentation (NRC, 2012). These science education approaches are grounded in a socio-cultural perspective that emphasises the importance of language in building science content, weaving the science narrative, and shaping interactions in the educational process (Scott, 1998). Language, hence, shapes the science knowledge being constructed and the process by which teachers and students construct this knowledge.

Teaching and learning science, from this socio-cultural perspective, requires the active involvement of students and their ideas (often everyday concepts) in the meaning-making process alongside the ideas proposed by the teachers (science concepts) (Andrée, 2005; Mortimer & Scott, 2003). Teachers use language to mediate this process when helping students learning, for instance, when building links between particular ideas (Fishman et al., 2017). Two discursive tools that are relevant to our educational perspective are communicative approaches and pedagogical link-making. Communicative approaches (Mortimer & Scott, 2003) focus on how teachers help students in the process of developing science ideas according to the socio-cultural model of learning. Pedagogical link-making (Scott et al., 2011) refers to the process of explicitly connecting ideas during the teaching-learning process. There are three different types of pedagogical links: links promoting the construction of knowledge by connecting concepts semantically, links promoting continuity of the science story and the teaching-learning process by connecting information temporally, and links fostering emotional engagement by eliciting the role of participants in the meaning-making process. While it has been discussed that students' emotional engagement in science is related to specific activities, such as demonstrations or experimental work (King et al., 2015), it is through linking different viewpoints students can be engaged in whole-class discussions (Lehesvuori et al., 2019).

In connection with the role of pedagogical links in knowledge construction, we find in the literature some studies showing the effect on learning results of how concepts are connected to facts and interconnected to other concepts during the teaching (Mayer, 2002). There is also preliminary evidence that the connection and links between scientific concepts and the extent scientific concepts are linked to create the scientific storyline has an impact on student learning (Schlotterbeck et al., 2020; Viiri & Helaakoski, 2014). Conceptual networks and maps have been constructed to present to what extent different concepts are linked together and models of conceptual networks have been portrayed in order to grasp the holistic picture of the scientific contents of the classroom discussions (Caballero et al., 2017; Schlotterbeck et al., 2020). However, as noted by Viiri and Helaakoski (2014), it is still to be studied how teachers could orchestrate this link-making and knowledge building in whole-class discussion.

There are still limited studies exploring how pedagogical link building takes place in teacher-orchestrated dialogue in terms of building knowledge and developing the scientific storyline through communicative approaches (Scott et al., 2011; Staarman & Ametller, 2019). Therefore, we have little evidence linking, in detail, the interplay and mechanisms of classroom interaction addressing both content presentation and different features of talk. In this study, by considering together two essential aspects of discourse in teaching and learning science, the nature of discourse (communicative approaches) and pedagogical link-making, we aim to deliver a more in-depth understanding of discourse and its quality. To do so, we will focus on two ideas: discourse coherence and pedagogical links authorship.

Coherence has been used in science education literature to study the relation between different elements of teaching and learning science. The term has been used to address, among other topics the relations between different parts of the curriculum (Sikorski & Hammer, 2017), the relation between teachers' views and their practice (Tsai, 2007), or the coordination of different parts of instructional practice (Newmann et al., 2001). In these studies, coherence is used to mean different things: relatedness, consistency, coming together or even correctness. In our case, we want to explore coherence as part of the classroom discourse. Discourse coherence has been addressed in linguistics and discourse research (Bublitz, 2011; Halliday & Hasan, 1976; Tomasello et al., 2005; Wang & Guo, 2014), but studies focusing on coherence as a linguistic feature in science classroom discourse are very limited. There are some studies showing that science classroom language and activities (Tiberghien et al., 2005), as well as representation of scientific concepts (Nieminen et al., 2012), should take place in a coherent manner in order to enhance the construction of scientific knowledge. How it relates to specific features of classroom discourse is not yet well studied. However, as we will explain in the next section, we pose that coherence is connected to intention and, when studying communicative approaches and pedagogical links from this point of view, it becomes clear that it is very important that teacher and student share the same intention when conducting activities, and particularly when making meanings through joint and collective discussions (Alexander, 2006).

As we have mentioned, socio-cultural theories of education place students' ideas at the centre of the learning process. To us, this entails that, not only students' participation is taken into account in the teachers' decisions regarding communicative approaches and pedagogical link, but also students' agency is crucial (Trauth-Nare et al., 2016) in the enactment of those two elements of classroom discourse and their efficiency in the teaching-learning process. Students are not passive recipients of classroom discourse, they co-construct it with teachers both by proposing discourse elements and by the way they decide to engage and respond to teachers' discursive proposals. Therefore, in this study, we suggest that it is not only whether links are being made in discourse or which communicative approach is put forward by the teacher but, rather, we shall also consider who makes these links, how they make them, and how students contribute to define the communicative approaches. The focus on authorship is connected to intention and, hence, with the other focus of this paper, how coherence could play a role in this process in terms of mutual understanding of the nature and purpose of discourse by the participants (Wang & Guo, 2014).

Theoretical background

Communicative approach

Assessment of the interactions depends on the theoretical propositions and how they will be translated into specific methodological approaches for the capture and analysis of the features of the data. One way to access complex and temporal features and to build a more overarching understanding is through the concept of pedagogical link-making (Scott et al., 2011) to explore how concepts are linked together in time via different forms of classroom interaction, i.e. communicative approaches (Mortimer & Scott, 2003). We have addressed this implicitly when demonstrating a model of cumulative

teacher orchestration of classroom discussion and activities building as a meaningful framework for learning (Lehesvuori et al., 2013). The construct of pedagogical link-making brings together aspects of how content is built and presented throughout the teaching, elements of how the role of students in the instructional process are managed and is also connected to the forms of instantiation of discourse and interaction. These three levels correspond to different temporal fields and, hence, pedagogical link-making is useful to approach the connection of the different purposes and temporal dimensions of classroom discourse (Lehesvuori et al., 2013).

Mortimer and Scott's (2003) framework for describing classroom discourse is an application of socio-cultural theory to the description of science classroom discourse where the teacher is a participant. It proposed four categories generated from the combination of two dimensions: interactive/non-interactive and authoritative/dialogic. Interactive talk allows students to take part, whereas non-interactive talk refers to moments where only the teacher talks; and whereas the dialogic approach considers diverging ideas and works with these contrasting views, the authoritative approach focuses on a specific point of view, usually the scientific view. The authoritative and interactive communicative approach is often indicated by traditional triadic IRF-patterns (I stands for Initiation; R stands for response of a student; F stands for teacher feedback) of interaction (Sinclair & Coulthard, 1975). In triadic IRF-pattern teacher questions are often closed by nature seeking for right answers and student responses are often followed by teacher's evaluative feedback (Lemke, 1990). In contrast, dialogic and interactive communicative approach is often indicated by teacher's open questions (Chin, 2007), student extended responses (Boyd & Rubin, 2006) and teacher probing follow-up (Cullen, 2002) leading to more chained patterns of interaction (Scott et al., 2006). As student ideas and thinking are elaborated, a dialogic communicative approach may also trigger student further wonderment indicated by student questions (Aguiar et al., 2009).

The choice of a particular communicative approach by the teacher has the function of leading the group into one of the phases of learning and, hence, the orchestration of communicative approaches is intended to guide students through their learning process according to socio-cultural theory (Lehesvuori et al., 2019; Mortimer & Scott, 2003). Decisions on which particular communicative approach to use, and when to use it, are context dependent. Among other aspects, these decisions are predicated on the particular topic being taught. Hence, it is an example of situated meaning, where each communicative approach has a 'pedagogic function' with a different situational purpose (Mortimer & Scott, 2003). Whether this function is appropriate at a given point of the learning process depends on the specific class context and the learning paths of the students at the moment in relation to the teachers' planned actions (Lehesvuori et al., 2011), based on their didactical knowledge of the topic. The assessment of these elements, seen from a particular pedagogical perspective, leads the teachers to decide on a particular pedagogical intervention, for instance, to orchestrate social languages (everyday discourse and scientific discourse; Renshaw & Brown, 2007), or to probe understanding (Scott et al., 2006), or to present new information. That is, teachers' pedagogical intention leads them to choose the communicative approach that better fits such intention. This allows teachers to influence the learning process of the students by using the pedagogical function of language (Msimanga et al., 2017) in one of its possibilities: the one that is consistent with the teacher's intention at this point.

Pedagogical link-making

When addressing the connection of the elements of the science teaching and learning process Scott et al. (2011) focus on the linguistic resources used in the science classroom to make reference and connect parts of the discourse to explicitly mark the links between different teaching moments (continuity links), different ideas, or expressions of those ideas (knowledge building links), and to their contributions to the joint construction of meaning (emotional engagement links). While communicative approaches focus on the managing of the teaching-learning process where language is the mediational tool of that activity, pedagogical link-making refer to both the process of meaning-making and the knowledge being constructed. Hence, while continuity links address the dynamic nature of classroom interaction within past experiences and ongoing experiences are connected to future ones (Dewey, 1938/1997), knowledge building links are representations of the knowledge that can be described as constructs of 'scientific models', involving explanatory and conceptual elements and relations. The scope of the pedagogical link-making construct is useful to analyse classroom discourse focusing on its structure rather than on the specific content. This makes it a good analytical fit to communicative approaches.

The presence of these links are essential for students to be able to construct their scientific understanding (Karlsson et al., 2020). Intuitively, it would be expected that students build these links themselves, yet the teacher's role is crucial in this challenging process (Fishman et al., 2017). Furthermore, as with all constructed knowledge in socio-cultural theory, the construction appears first in the social plane and it needs to be interiorised later (Scott et al., 2011). From a social constructivist perspective (Kozulin et al., 2003; Vygotsky, 1978), the construction of knowledge requires taking into account students' existing knowledge and, hence, the social plane cannot be an exposition of the finished knowledge, it has to contain different views and voices (Bakhtin, 1986) including the students' understandings.

A socio-constructivist teaching will include planning and conducting activities to assist students in their work of constructing new knowledge as a way of preparing the internalisation (Wertsch, 1985), providing the tools they will require. With this in mind, it is obvious that both the teacher (who provides the links, or enough of them to assist students) and the students (who have to make those links themselves in order to learn) need to be engaged in link-making. But, this does not mean that they are both necessarily making the links at the same time.

Links can be presented as an explicit way of showing the internal structure of the knowledge to be constructed, they can be offered as a way to reinforce the knowledge being constructed, or as a means to scaffold the construction. The nature of the links can influence the teachers' choice of communicative approaches but there is no univocal relation among them. For instance, dialogic communicative approaches are needed to establish knowledge-building links between everyday ideas and scientific ideas seems clear. But, in other cases, dialogic approaches won't be required or even advisable (Scott & Ametller, 2007; Wells & Arauz, 2006).

Coherence, intention and participation

From a linguistics perspective coherence is used to talk about the connectedness of language production (Bubliz, 2011), to what makes a text or discourse a whole and

not a set of disconnected clauses. While there are specific language elements that can be connected to coherence – usually referred to as cohesion from this perspective (Halliday & Hasan, 1976) – coherence is a semantic construct which fundamentally accounts for the establishment of local contexts of interpretation of different parts of the discourse so that they form a comprehensible whole allowing effective communication. In our case, this relation to contexts suggest that pedagogical link-making will be connected to the production of coherence in the classroom discourse. In this study, we particularly draw on the type of interpersonal coherence (Halliday, 1978) addressing how speakers take up positions and express their roles in joint discussions (Davidse & Simon-Vandenbergen, 2008). These positions and roles are projected in teachers' use of communicative approaches (Mortimer & Scott, 2003).

To put forward a particular communicative approach is to choose an ensemble of linguistic (and non-linguistic or multimodal linguistic) elements that will allow the rest of the participants to recognise the teacher's discourse and then to decide how to take part in it. The response of the students, their participation, will depend on the decisions they take in terms of how they see the activity and how it is related to them. External elements, such as power relations (Candela, 1998; Cornelius & Herrenkohl, 2004), and internal elements, such as the student's knowledge and interests (Linvill, 2014), will shape the student's intentions, which will lead to decisions on how to take part in the discourse. The way students participate in discussion could also be dependent on the students' shaped identity and the role they take in discussion (Moje, 1997). It has been discussed that dialogic approaches could enhance more elaborated participation in the long term as students become more involved as active contributors to science discussions (Kumpulainen & Rajala, 2017; Trauth-Nare et al., 2016). In relation to this, it has been shown that for example intentional use of personal pronouns can be aligned with teachers intentions in the purposeful use of different forms of interaction (Oliveira, 2009). Personal pronouns can also be considered as linguistic clues when it comes to the level of personal authority and formation of discourse identity (Andersson & Wagner, 2019; Wagner & Herbel-Eisenmann, 2014). For instance, we have previously pointed out how the use of 'we' can enhance more dialogic and joint construction of knowledge (cf. Kumpulainen & Rajala, 2017), whereas use of 'I' and 'You' provokes teacher's personal authority and prevailing asymmetry in scientific discourse (cf. Lehesvuori et al., 2018).

While teacher leads the process of scientific discourse and meaning-making, it can only happen in the productive way (envisaged by the teacher's pedagogical intention), if the intentions and participation of the actors align (cf. Chase et al., 2019). Therefore, it is very important that the teacher's choice of linguistic elements constitutes a coherent pattern of discourse that students can recognise and align with. In other words, there must be a coherence between the pedagogical intention of the teacher and his/her participation in the classroom discourse (which includes how it develops in time). If intentions do not align or they are not understood across by the participants, then communication is linguistically incoherent (Tomasello et al., 2005). There are limited educational studies explicitly pointing out how this incoherence manifests in science classrooms. The intention-participation coherence is not a guarantee of educational success. The choice of a communicative approach is rooted in pedagogical content knowledge, educational psychology perspectives, the students' in their learning process at that time. Therefore, even if the participation of the teacher is coherent with his

intention, there will be an incoherence of a different kind, not intention-participation, but intention-students' need. This incoherence is underpinned by discrepancies in what students know/can do and what the teacher is proposing them to do. Communication is also underpinned by these matters, hence, it will be affected by this type of incoherence as well. *To understand how different factors affect coherence would be useful for teachers and teacher trainers.*

Research questions

The research aim derives from the presented theory and our choice of considering both communicative approaches and pedagogical link-making in characterising science classroom discourse. Considering these two aspects we shall explore:

– How is consistency enhanced in communication and pedagogical link-making in three case teachers' orchestration of classroom discourse on the topically identical teaching sequences?

Through the three explorative cases, we will show how coherence is established in communication and how pedagogical link-making facilitates continuity, emotional engagement and knowledge construction.

Method

Participants and data collection

The data was collected within an international (Finland, Germany, Switzerland) video study (QuIP, Quality of Instruction in Physics). Although the data was collected in 2008–2009, the uniqueness of the data in terms of including 25 different Finnish teachers teaching the same topic (electrical power and energy) makes it valuable to address new research problems. The students were 9th graders (averaging 15.6 years of age). Each video-recorded unit (double lesson) is approximately 90 min long. Eleven of the teachers majored as Physics, eleven as mathematics, and three as chemistry teachers. In Finland, in addition to pedagogical studies (Bachelor's degree) science teachers are often required to have a Bachelor's degree in science/mathematics subject in order to be qualified to teach the subject. All the participants were volunteers.

The lessons were video recorded with two cameras: one following the teacher and one fixed to capture the whole-class. The teacher wore a portable microphone and 4 microphones were located around the classroom in order to capture student responses if not audible in the main camera and microphone. The original selection of the schools and teachers for the study followed criteria set in international comparison studies (see Fischer et al., 2014).

Selection of the case teachers and the extracts

Previous research has included a more structured analysis of the types of questions, feedback types and interaction patterns leading to further consideration of communicative

approaches taking place at episode-level (Lehesvuori et al., 2013). While the structured approach to analysis of the whole dataset is opened up elsewhere (Fischer et al., 2014), this study follows a more open, unstructured, and fine-grained approach to explore phenomena that cannot be otherwise detected (cf. Kelly et al., 2020).

When it comes to this study, the initial segmentation for analysed episodes was based on detecting changes in activity, topic or communication. The activity in all of the selected cases is a whole-class discussion initiated by the same question, at the same time marking the beginning of an episode. Whereas the end of an activity, and this episode, is signalled by linguistic markers in Teacher B and C's cases, Teacher A's extract is cut off soon after the introduced target concept 'work' despite the ongoing whole-class discussions. This is due to the research purposes and space limitations of this article.

Although the topic being taught was the same, the similarity between some Finnish lessons and episodes and even initiations was surprising (Lehesvuori et al., 2013). This unique similarity in some features led to the selection of extracts from Teachers A, B and C. First of all, the same anchor question: 'What does it mean that something or someone is efficient?' and the same target concept 'Work' was detected. In addition, outlined by the same initiation and target, the episodes constitute a similar form of an activity, that is, as noted, teacher-orchestrated whole-class discussion. Thus, as episodes are built of the same initiation and target and activity type, the setting sets the fruitful ground for a more detailed comparative explorative analysis of cases. The cases and teacher's pedagogical link-making actions can be initially described as follows: Teacher A is trying to get students to make the link through inconsistent use of communication; Teacher B is bringing in students' experiences and engaging students in to discussion while making the link herself; Teacher C is opening up dialogic space for students to make the link.

Despite many similarities between episodes, there is a contextual temporal difference for when the anchor question is posed, especially in Teacher A's case (Table 1). In her case, the lesson begins with a student group's experimental work on an electric engine and the extract follows right after. This experimental work happens after the selected extracts of teachers B and C. In these cases, the lesson begins similarly, checking the homework.

Data analysis

Our theoretical choices put the focus on the different roles language can play in science education, e.g. structuring the scientific knowledge and managing the learning process.

Table 1. The temporal context of the example episodes.

Episode	Teacher A	Teacher B	Teacher C
Pre	Checking homework and group experiment on electric engine	Checking homework and introductory cartoon	Checking homework
Example episode	Whole-class discussion initiated by anchor question: *'What does it mean that something or someone is efficient?'*		
Post	Whole-class discussion continues with introducing and discussing waterfall analogy	Student assisted teacher demonstration on electric engine	Teacher demonstration on electric engine

To analyse our data from this perspective, we have underpinned our analysis with ideas from functional linguistics (Gee, 2010, 1999; Halliday, 1978), where language is considered to be used to do things, to act on the world, to have functions. In our data, any instance of language use will have at least a function and, often, it will enact several functions at the same time. Thus, the same utterances may be opened up from different functional perspectives in the presentation of the analysis.

In the analysis of the episodes, we build pivots on two concepts to describe elements of the science education discourse – communicative approaches and pedagogical links – and one concept to describe characteristics of the resulting discourse – coherence. The aim of the analysis is to better understand how classroom discourse (as analysed with these concepts) can help us understand the teaching and learning science process and results. Thus, in the presentation of the results we proceed in the following order: (1) Presenting turn-by-turn transcriptions of the interactions and setting up the context of the teaching episode; (2) Pointing out emerging features of communicative approaches and pedagogical links; (3) Consider consistency in the use of communication approaches and pedagogical links between teacher and connecting it to the analysis of discourse coherence in that particular episode.

Coherence to precise definition, and hence the methodological and analytical approaches used to study it, are still debated. Halliday and Hasan (1985) put forward a set of language elements that are used to provide coherence. We refer to some of them when we feel they are or particular interest (such as the use of pronouns) but we have focused on the context of interpretation afforded by participants at different points of the discourse and analyse whether they are successful in providing a coherent discourse or not. Here it is important to highlight that we are analysing a 'text' that has been generated through interaction in the classroom settings, hence we need to make assumptions, based on participant interventions and our knowledge of the educational context, of whether the participants were experiencing a coherent discourse while it happened. To do this, we will have to introduce our analysis of the participants' intentions in relation to the functions played by the discourse. Consistency in communication may be indicated for example in use of personal pronouns (Oliveira, 2009), which can also be linked to interpretations of authority (Andersson & Wagner, 2019; Moje, 1997; Wagner & Herbel-Eisenmann, 2014) and communicative approaches (Lehesvuori et al., 2018).

The judgement of the communicative approaches is partly based on the nature initiations of the teacher, student responses and teacher feedback taking place in transcribed turns. Although dialogic communicative approach can be interpreted in more chained patterns of interaction within teacher probes students further in their thinking (Scott et al., 2006), also the triadic pattern may indicate dialogic stance by the teacher (Wells & Arauz, 2006). Thus, instead of applying structured coding with pre-defined codes and judging the communicative approaches merely based on the single turns and formed patterns of interactions, a more open data-driven approach is implemented in exploration of the cases (Yin, 1994). That is, teacher communicative intentions will be detected through consideration of data emerging linguistic features (Hsu et al., 2009).

When it comes to different types of links, continuity links can be found for example in explicit organisational metadiscourse connectives (e.g. 'Now let us remind ourselves'; Tang, 2017). Whether students' previous experiences and views are linked to the

topics discussed, this also serves *linking for emotional engagement*. Link-making between scientific concepts serves *linking for knowledge building* and can be found in both teacher and students' utterances (Scott et al., 2011). *In relation to authorship,* we shall consider how and by whom the link is made, and whether it was intended by the teacher. For example, it'll become evident in the first case that it is the teacher's intention to make students build the conceptual link, which will be pointed out through careful scrutiny of linguistic indicators such as personal pronouns and intonational features (cf. Lehesvuori et al., 2018).

Trustworthiness

The selection of the cases was based on the first author's initial research on detecting open questions and analysing the following interactions (Lehesvuori et al., 2013), leading to the discovery of similar initiatives for whole-class discussions. This led to a purposeful selection of examples unveiling the studied phenomena (Patton, 2015), which is common for explorative case studies (Yin, 1994). After finding the three cases to be explored further, the turn-by-turn transcriptions were shared to the second author who independently analysed and interpreted the data. After the first round, it was found that whereas the first author had focused more on the nature of discussions, the second author emphasised more the analysis of pedagogical link-making. The common aspect emerging from the analysis and interpretation was the level of coherence and consistency, thus leading to the selection of this concept for further theoretical conceptualisation and empirical exploration. The interpretations of the micro-scale analysis were checked in workshops including colleagues (of the first author) from different departments of teacher education and applied linguistics. This way multidisciplinary researcher triangulation can be considered to take place as different independent researchers from different fields of research have interpreted the same data (Miles & Huberman, 1994).

Findings

In this section, we shall explore three episodes which include questions covering the same topic. In all the cases teachers look back to how power was defined in the mechanics course via an open root question similar to: 'What does it mean that something or someone is efficient?'. This question is posed in a workbook with a two-pronged purpose of reviewing the definition of power in mechanics in order to introduce and build a link to the definition of power in electricity. The question was adapted differently in each case as a whole-class discussion. All of the three episodes conclude with the same conceptual target anchor – work (bolded in transcript examples).

Teacher A: getting students in to make the link

Previous to the episode we analyse here, students have conducted in small groups an experiment with an electric engine and a lamp. After the experiment, the teacher begins the following whole-class discussion by reading the opening question from the workbook.

Turn	Transcript
1	You are being asked that … ((reads workbook)) that, at what point is the electric engine being the most efficient? ((note: in the following transcripts the term efficiency is often used when referring for example to a person or something being efficient in terms of doing something with a certain amount of energy. And, power is often considered in the context of equational definitions such as $P = E/t$ and $P = UI$. In Finnish language effectivity and power can be both approached with the same word 'teho'. In the translated transcripts the link building between definitions of power in mechanics and electricity begins from effectivity as being suitable for describing a person converting energy to mechanical work))
2	What does being efficient mean?
3	Now it is about the final call for you to remember what was taught in the course within mechanics was addressed ((pause and waits))?
4	That what we ((cuts the sentence)), can you recall for instance an example which we used to think about the efficiency in autumn? ((students are looking at their textbooks and writing something)). Well whose brain cell lights up ((a student begins to talk))
5	Student1: Well, is it like how it produces and gives up the energy?
6	Yeah it might have got something to do with energy ((rising intonation, waiting for further ideas))
7	Well, you were thinking about the books and lifting them at the table. What did we discuss, what, what we, how efficiently did we get them up? ((student begins to talk))
8	Student2: All the books are lifted at the same time
9	All at the same time ((repeats with lowing intonation and continues)). Why is that so efficient then? Why was it not efficient when lifting one book at the time? ((Student3 interrupts 'It's slow' and teacher gives a turn))
10	Student3: ((repeats)) It's slow
11	It's slow ((repeats with lowing intonation)). So, what are the things that have an effect on someone's efficiency
12	Student4: Time
13	Time ((repeating with rising intonation and nodding, wait for further responses with no further response))
14	Well does someone remember the equation for power? What else than how fast we do things is in the equation for power?
15	Student5: Weight
16	Well weight was there yeah ((neutral hesitation, waits for further responses and begins to demonstrate the lifting action)). Even though I lift this rock ((imaginary rock)) quickly to the table?
17	Student3: Was it time?
18	What else has an effect than time?
19	Student5: Weight
20	How did the weight effect then?
21	Student7: The force of gravity had an effect and resisted it?
22	Force ((repeats with rising intonation)), yeah but not the force only but ((waits for extension))
23	Well what ((mitäs)) did the power describe then? The power describes how fast you do ((leaves a slot and waits for someone to fulfil the sentence for several seconds)). ((Student tries to look for the answer from the textbook)) Well it is not in that book, it's in the old book. ((still waiting))
24	Well, does work ((stresses conclusively)) relate to it in any way? Did it tell you how fast you do the work?
25	Students: Yes
26	That how fast you do work. Can it possibly relate to the electric lamp or engine in anyway?
27	Students: Yes
28	And, what is work then?
29	Student2: It is the energy that is transferred
30	It is the energy that transfers ((repeats with lowing intonation))
31	Student1: Well that's what I said in the beginning?
32	Yeah, that's what you said. So how much energy is transferred in unit of time, so how much work is done in unit of time. So it is asked from you that what kind of lamp or engine is efficient? What kind of engine is efficient? ((no response so teacher asks another question)) Well what kind of lamp is powerful? Is it easier to think about the lamp?
33	Student2: It shines brighter
34	It shines brighter ((repeating with rising intonation)). Why does it ((cuts the sentence)), why is brighter lamp more powerful than more dimmed one? ((continues the whole-class discussion))

Setting up the activity: flashback and lack of definition

The episode begins with two questions of different nature. The first question (Turn 1) points at the experiment students just conducted while the second question (Turn 2) opens the floor to recover the description of power which was constructed in a previous

semester. The intention of the first question is to elicit a correct explanation, the second foregrounds the teacher's intent to find the link between mechanical and electrical definition of power.

Teacher A starts making the pedagogical link at the end point (the work with the engine) and then tries to project back the students to the time when they worked on mechanics (continuity link) (Turn 3). This way students should answer the question at hand, on electric power, using the concepts of power previously discussed in the context of mechanics (conceptual link). The teacher seems to think that students should be able to do this 'flash back' link on their own, that, maybe, the work with the electric engine should have been enough of a primer for students to make the connection that is required to be used, and fleshed out, to answer the question.

The beginning of the questioning sequence is a struggle to get any response and reaction from the class. Teacher reading the question from the textbook does not signal the teacher's own interest towards student ideas, rather it foregrounds the instructional setting of finding pre-defined answers (Moje, 1997), despite the open nature of the question. The judgemental 'Now it is about the last call for you to remember … ' (Turn 3) reinforces this, and most students are looking at their textbooks in search of right answers and do not take eye contact with the teacher. The previous line is very evaluative by nature, while the teacher is seeking more of a 'fill in' response from students.

Closed questions and dialogic markers: sending mixed messages when enacting communicative approaches

The lack of clarity in the presentation of the activity is mirrored by shifts in discursive features. At first, this is indicated by a mix of different types of questions (Chin, 2007). Through the episode, we see an inconsistent use of 'You', 'We' and 'Whose' signalling how the teacher shifts the responsibility back and forth from collective to individual (Oliveira, 2009). We do not have evidence on teacher thinking, but we may question whether the teacher is trying to soften the 'Final call for you to remember … ' (Turn 3) with the more collective pronoun 'We' in the cut off sentence 'That what we' (Turn 4). All in all, it is the linguistic clue 'You' in turn 3 that highlights the teacher's personal authority and students' role merely as demonstrators of knowledge rather than equal participants of a dialogue (Moje, 1997). Without leaving the discussion at the collective level via 'We', the teacher gets back to 'You' via 'Can you recall, for instance, an example which we used to think about the power in fall?' (Turn 4).

We think that these shifts contribute to a misalignment between the teachers' aim and that perceived, and acted upon, by the students, both in terms of the communicative approach and of who is to be the author of the link. It is increasingly evident that Teacher A intends students to build the link. This is confirmed by a sarcastic comment 'Well, whose brain cell lights up' (Turn 4) which signals the teacher's frustration. The problem is not that students are unwilling to participate. Even though it has been shown that sarcasm does not help in creating a positive climate for classroom interactions (Hamre et al., 2013), a student responds and brings in the concept of energy (Turn 5). The problem seems to be that students do not understand what is asked of them and this is connected to how the teacher presents the pedagogic links in his discourse.

Hinting pedagogical links and leaving them open: waiting for students' authorship of links instead of making links or providing clear anchors

The teacher starts with a question which immediately reformulates to the core conceptual element (power) and when no answer is presented she mentions where in the past they should go to look for information. In turn 4 he begins to reformulate the question, but stops herself and continues narrowing down to the example from the previous semester. Even when his interventions provide pieces of information about the link (the anchor episode from another course in turn 7 and anchor concepts in turn 14), Teacher A does not clarify what she expects the students to do. Students are not told what to link and what to build. And, when being asked about things already taught (Turn 7) with closed questions respond to them as openings to an authoritative interactive approach. Therefore, students provide short, often tentative, answers which the teacher follows up by not providing an evaluation, or doing so only by a lowing intonation (turns 9 and 11). Controversially, with a rising intonation in feedback (Turn 13) or a follow-up question (Turn 18) inviting elaboration a more dialogic interactive approach is emergent (Lehesvuori et al., 2018). Different communicative approaches are used to direct students to the desired outcome: Authoritative moves signal no process and undesired direction and dialogic moves hint for the target being closer and to be obtained by students. This incoherent discourse, in terms of communicative approaches, hinders the sharing of aims which affects the identity of the discourse and the development of the activity (Kumpulainen & Rajala, 2017). A consequence of this is the failure in making the pedagogical link. The teacher is placing the elements of the pedagogical link in the social space while inviting the students to build (in her mind might be a re-building or remembering) the conceptual link themselves. The result is that, even after the anchor episode from the previous course is clear, the interference of the unresolved knowledge-building link ends up leaving the pedagogical links unresolved.

Unshared aims and incoherent actions leading to frustration

Overall, the teacher has a very clear answer in mind from the start and only uses the students' answer to select the conceptual pieces she needs to build that answer (which in her mind maybe they should have been able to provide from the start) finally stated in turn 24. However, her choices for the discourse (communicative approaches) and construction of knowledge (pedagogical links) seem inefficient when it comes to educational dialogue and bringing these ideas fluently from students to the class discussion. The teacher's insistence in getting the link from the students mirrors a pedagogical decision of engaging students in discussion and contributing to link building, and all this at the cost of consistency.

A cultural event, the identity of the discourse (its dialogic or authoritative nature) is defined by the participation of the speakers which is grounded in their intentionality which, in its turn, is shaped by their interpretation of the other speakers' intentionality. It is quite clear that there is a mismatch of intentionalities and their interpretations by the speakers, which is even verbalised in turn 31: 'Well that's what I said in the beginning?'. The teacher, whose intentionality is recognised in the classroom situation as being the one that should be first understood and then followed by the students, seems to start with an intention (getting the answer that is already there) and proposes a particular discourse identity (authoritative interactive), but the students do not follow her. We suggest that they understand the initial intention, but do not have the knowledge because the

content link has not been modelled for them. Afterwards the teacher is trying to engage the students, but her intentionality is interpreted by the students as being evaluative-authoritative and, hence, provides brief answers which refer to the specific question at hand. The teacher takes these answers and slowly builds on them to construct the conceptual link she is looking for.

Teacher A misunderstands the challenge students face to answer her questions, and hence he does not provide adequate scaffolding. Her hesitant and inconsistent use of the discourse has placed the students in a defensive/passive position which not only makes a dialogic engagement impossible but also seems to stop students from remembering – or at least volunteering what they remember. Students, faced with closed questions intending to obtain a correct answer, and not having a clear understanding of the teacher's intentionality are going back to the anchor episode but not to relive it as a learning packet but to 'blindly' look for the piece that serves as the answer. Seeking for the link reinforces the institutionalised form of interaction where students merely fill gaps of information as requested by the teacher (Moje, 1997). Based on the above notions, it can be concluded that incoherency is manifested in communications in both intention-participation and intention-students' need dimensions of coherency.

Teacher B: building on students previous experiences to foster continuity when building the link

The lesson has begun with checking of the homework and presenting an introductory cartoon with a topic of power and energy consumption. After this Teacher B opens up the example episode by taking students back to course and a lesson where power was addressed in the context of mechanics (Turn 1).

Turn	Transcript
1	Okay, let's see whether the 8th grade mechanics would come back to mind ((organisational metacognitive connective)). Then the power was talked about for the first time with you, or the sub did talk about it with you. Can you recall what power means? ((waits for several seconds))
2	Well you had the kind of lesson where you ran the school stairs upstairs and your friend took the time. Can you remember?
3	Students: Yes
4	Yeah, you do. And, power was measured right! Well, what means to be efficient then, who of you was the most efficient?
5	Student1: Probably me ((student one raises hand and other students are laughing))
6	((teacher joins the laugh)) Yeah, I sure believe it's you! Why was Jon the most efficient?
7	Student2: He was so fast! ((confidently))
8	Yeah, he was so fast! ((repeats with rising intonation and waits for further response)). So, what it is about with the power then?
9	Student3: About time
10	Yeah, it's about how fast someone does something. And, Jon was the fastest of you running from down to upstairs. So, power describes how fast work is done. Did you talk about how power can be measured for electric devices too?
11	Students: Yeah; Sure; Yes ((several students saying and nodding))
12	Yes, of course you can ((passive)). Today we're actually going to talk about electrical power.

Opening up opportunities to promote students' engagement

Opposite to Teacher A, Teacher B does not directly read the question from the workbook. She begins with a question pointing the students to the topic of mechanics

taught in a previous semester (as an anchor to a continuity pedagogical link) and asking about the concept of power (as an anchor for a conceptual-knowledge building pedagogical link) (Turn 1). As there is no answer, the teacher formulates a more explicit question including explicit reference to a classroom activity from the previous semester (Turn 2) leading to students' joint response in Turn 3. Teacher B continues by drawing attention to power and formulating the question so that students can answer with information of either the anchor episode or the concept discussed in that episode (Turn 4). One student (Jon) answers and other students join in laughter (Turn 5). The teacher has successfully engaged the students in the activity while drawing their attention to the anchor episode starting to make a pedagogical link with continuity, conceptual, and personal dimensions.

Coherence in the enactment of pedagogic link-making and communicative approach leading to a clear, shared, aim

Teacher B is now able to pose a 'Why' question in order to delve into the reasons for why Student 1 (Jon) was the most efficient (Turn 6). After this, Student 2 delivers (Turn 7) a likely expected response and Teacher B's repetitive follow-up with rising intonation and wait time indicates that more explanations are welcomed (Turn 8; Lehesvuori et al., 2018). However, after getting no instant responses the teacher narrows back down to the definition of power, which leads to Student 3's response 'About time' in turn 9. In turns 10 and 12 Teacher B brings students back to the topic of the day and electricity.

The teacher uses language to indicate her interest in students' memories so that, even though her opening questions are asking for recall, they give students enough latitude to participate even if they do not have the complete answer. By making it explicit that she was not there ('a sub did'), the teacher places on the students the task of describing the anchor episode signalling a shift of the ownership of the ideas and memories (Lehesvuori et al., 2018). This also reduces the personal authority that could be signalled through the use of the personal pronoun 'You' as the teacher excludes herself as being someone who would also remember what has been taught. This opens up the space for students to use their experiences and linking them to the question of power. These choices enhance dialogicity to build and maintain the kind of participation that she will require for the conceptual work that will come later on. Another marker for authentic and open classroom climate is the sincere laughter in Turns 5 and 6 (Pianta, Hamre, & Mintz, 2012).

Effective teaching: establishing common aims and engaging students

Teacher B is very clear at communicating her intentions to the students and getting them to share her aims and to be engaged in the activity, this way building on the intention-participation dimension of coherency. Contrary to teacher A, who seemed determined to get the students to make (most of) the pedagogical link, teacher B identifies the classroom episode that will serve as an anchor and makes the conceptual connection (she is the one that connects power with work). However, the way she enacts the work on the pedagogical link fosters the students' personal engagement and offers them the space to contribute to the authorship of the link. The episode has served the purpose of preparing the group to start learning together bringing us to weighing the intention-students' need the dimension of coherency.

Teacher orchestration is characterised by consistency and effectiveness as she takes an active role in making the conceptual link at the same time successfully linking student personal experiences strongly to the process. Both of these aspects are foregrounded right from the beginning through the organisational metacognitive connective: 'Okay, let's see whether the 8th grade mechanics would come back to mind' (Tang, 2017). In this way, Teacher B fosters continuity in both conceptually and student experiences although hanging on to the authorship of the link-making process. Next, through the last case example, we may question whether dialogicity is hindered in cost of effectiveness and whether this is relevant in meaningful learning.

Teacher C: opening up for the link and maintaining the dialogic space

After wrapping up the checking of the homework, the example episode begins with the teacher introducing the day's topic on the blackboard. So far, he has only written down the title 'Power' and the abbreviation for power ('*P*'). After this, he shifts from blackboard towards students and begins the whole-class discussion. Thus, again different from Teacher A, there is no student work conducted yet.

Turn	Transcript
1	Well what does it mean in terms of mechanics when it comes to someone being efficient? ((moves from the blackboard towards students)). ((After waiting for a few seconds names a student)) Ellie!
2	Student1: Oh, when someone is efficient right?
3	Yeah! ((waits for elaboration))
4	Student1: Well isn't it when using little energy and getting a lot done? ((Student 2 continues right after))
5	Student2: Well isn't it how much work you do? ((Student 1 continues right after))
6	Student1: Yeas, with a certain amount of energy, and in a certain time?
7	Student3: More work is done
8	Well, you're on the right track ((mysteriously not revealing the correctness)). So how much work is done ((waits for fulfilment))
9	Student1: With a certain energy
10	Student3: ((adds to Student1)) In a certain time
11	In a certain time! It must be like that! You came up with energy and time that's all right. No worries! In a certain time ((like repeating students response)).
12	Then we played with a certain number of Joules and time. But now, let's move on to electricity. And, see what does the electrical power mean then.

Undefined link: concept driven call mixed communication choices

As in previous cases, Teacher C identifies the anchor of the pedagogical link he wants to make as the definition of power as it was constructed in mechanics in a previous semester (Turn 1). However, in this case, the teacher asks about power and leaves it to the students to identify that the word 'Power' in the blackboard is part of the anchor of the conceptual link he wants them to start building. While posing the initiating question teacher shifts from the blackboard closer to students. This proxemic shift could signal teacher decreasing his ownership of the ideas (cf. Lehesvuori et al., 2018) and a change in communication (Scott et al., 2006) from teacher-led to more student-centred. After a short pause (1 s), Teacher C names a student by name ('Ellie!') who confirms the question to be answered via repeating it (Turn 2). After getting the teacher's confirmation (Turn 3), the student continues by shaping her idea in the form of a question: 'Well isn't it so that using little energy and getting a lot done?' (Turn 4). This signals hesitation

when it comes to correctness (reference), and instead of the teacher replying to this question he remains silent. Thus, another Student (2) takes the space through a question/answer including the conceptual link 'work' (Turn 5). However, while the teacher is still remaining silent, Student 1 is now even more convinced of her initial response including 'energy', now adding 'time' to the list of considerable dependents (Turn 6). Conclusively, Student 3 takes part in the discussion and states: 'More work is done' (Turn 7).

In Turn 8 the teacher says 'Well, you're on the right track', which is not yet about declaring the correctness of student ideas, although the teacher is pointing out the conceptual link 'work'. Space is still open for student ideas as students review their ideas and the teacher picks up the other sought concept 'time' while not forgetting acknowledging the other response 'energy'. Compared to Teachers A and B, there is another component emerging from the example. Instead of being forced to prompt ideas from students (Teacher A), they have now delivered the parts for the definition of mechanical power. Teacher B does not make the link explicitly (as teacher B did) rather he begins the conceptual shift towards electricity.

Engaging students with an unclear aim

All in all, this extract can be considered to mirror dialogic interactions in terms of collectivity (Alexander, 2006) complemented via micro-indicators such as proxemic shift and supportive verbal cues ('Well, you're on a right track', '… that's all right', 'No worries!'). Even though the idea behind is to find certain answers building the conceptual link for mechanical power, the dialogic space (Wegerif, 2007) can be considered to be briefly open in terms of students replying in their own terms without the teacher directing the discussion. This is evident in the teacher posing merely two actual questions. Despite the teacher being coherent in communication (intention-participation), hence, successful at engaging students in a discussion, there is a lack of closure required to build an explicit conceptual link. This leaves us with uncertainty when it comes to the intention-students' need dimension of coherency. Whereas Teacher B's episode was characterised with efficiency as the teacher was making the link by herself, in Teacher C's case the link is not explicitly made here. However, we do not conclude here whether the link could have been made within a wider temporal scale, rather we may say that the authorship of the link-making is being left in joint possession.

Discussion

In this study, we focused on three cases of teacher's orchestration of classroom discourse to make the same conceptual pedagogical link. This link was prompted by a textbook question intended to recover ideas from previous teaching in mechanics and to set ground for the topic at electric engines. Each teacher formulated the question and pedagogical link in different ways, which already indicated a different framing and stance to the orchestration of the following whole-class discussions (Pimentel & McNeill, 2013). These differences were enacted through different choices in communication, communicative approaches and specific discursive choices, and pedagogical link-making.

Teacher B

Students are asked to recall the anchor episode to engage with the activity and contextualise the links the teacher will make. This factual recall fits with the authoritative interactive communicative approach teacher B successfully fosters. The shared aim reflects with coherence in communication (Tomasello et al., 2005) in both intention-participation and intention-students' need dimensions.

Teacher C

Students are asked to recall both the anchor episode and the science concepts constructed in preparation to engage with the new episode. This factual recall would be coherent with an authoritative interactive approach (Wells & Arauz, 2006), but Teacher C fosters a more dialogic interactive one. In other words, it can be evaluated that the intention-participation is successfully achieved, but intention-students' need dimension is not through the use of the dialogic approach.

Teacher A

Students are asked to make the pedagogical links. This is likely to imply a higher cognitive demand which would fit with a dialogic interactive communicative approach, but the teacher's enactment leads students to an authoritative interactive one. As a result of mixed signals in communications, incoherence in both intention-participation and intention-students' need dimensions is manifested. While dialogic moves could facilitate dialogue and students role as equal contributors in knowledge building (Kumpulainen & Rajala, 2017), it was merely used for luring students to make the pedagogical link.

Based on the above remarks, it can be discussed that even with a coherent alignment of aim, type of linking and communicative approach, the outcome will be affected by whether communication choices for the enactment of the activity are coherent with the proposed communicative approach. In both cases, teacher and students need to share the same aims in order to communicate productively. In other words, in order to build on interpersonal coherence (Davidse & Simon-Vandenbergen, 2008), participants' aims and intentions should align (Tomasello et al., 2005). It is valuable for teachers to understand that students need to be able to participate in the proposed pedagogical linking, i.e. they need to understand its aim and have enough information and knowledge to participate as authors of the links. Otherwise, they can either choose not to participate or change the aim so that it is coherent with the nature of the activity according to the information they have. The same can be said for the participation of students in dialogic interactive exchanges. Even though all cases resemble more or less institutionalised forms of science classroom interaction (Moje, 1997), it is through coherence in communication that teachers are likely to get students engaged in more productive meaning- and link-making processes also during teacher-orchestrated whole-class discussions (cf. King et al., 2015).

The importance of the coherence between implied communicative approaches, the activity as presented to the students and the discursive choices can be seen in our analysis as well. This relates to purposeful framing and how the teacher links activities and

content (Ford & Wargo, 2012). As an example of unsuccessful framing and linking the communicational activity to the content, Teacher A's requiring remembrance decreases the students' willingness to respond followed by more persuasive utterance finally leading to a response that causes a contradiction between authoritative opening and following more dialogic negotiation. Besides this, the lack of consistency in communicative approaches was also indicated by the incoherence in the personal pronouns (Oliveira, 2009) and intonational features (Davidse & Simon-Vandenbergen, 2008). Indeed, Teacher A's orchestration of classroom interaction can be described as inconsistent and leads to an interesting statement: The orchestration of talk should be consistent in content and communication. Teacher A has students trying to participate in a way that aligns with the participation intended by the teacher (cf. Chase et al., 2019). However, the educational and communicational activities fail because the students do not have the knowledge, or the ability to link the concepts that the teacher is expecting them to have. Indeed, in order to successfully engage in dialogue, and here link-making for knowledge building students should have some repertoire of the established common knowledge as well as willingness to share it (Wells & Arauz, 2006). Teachers should also be willing to evoke and elicit this knowledge, which is often not the case due to teachers' existing beliefs in students' capabilities and motivation to participate in productive whole-class discussions (Pimentel & McNeill, 2013).

In terms of communicational consistency, we pointed out Teacher C being able to open up authentic dialogic discussion with space to student autonomy and ideas (Wegerif, 2007). It was however left open whether the actual conceptual link between mechanical and electrical power was to be made more explicitly in forthcoming episodes. Derived by this, we consider that there should be continuity and link-making between concepts (Scott et al., 2011) fostering the temporal coherence. Extending this to dialogicity, there should also be links made between student previous experiences to ideas discussed. This was present in Teacher B's case as she brought student experiences to the social plane through whole-class discussions. Indeed, when building links between learned and to be learned, the internalisation process is provoked through discussions taking place in the social plane (Scott et al., 2011; Wertsch, 1985). This is an example of continuity fostered and strengthened by refreshing and bringing in students experiences and making it as a collective process as demonstrated by Teacher A.

Conclusions, implications and limitations

The result of this study implies that it is not only whether the link is made but also whether language is used in a consistent and coherent manner. Indeed, foregrounding the rationale for further research the learning gains indicate that coherence could play a role in learning as Teacher B's class had the highest learning gains in the whole dataset. Vice versa, Teacher A's discourse incoherencies mirrors low learning gains. Of course, we cannot make generalisations here, rather we suggest further studies conducted on pedagogical link-making and communicative approaches and especially on how they affect not only as separate functions but together and in connection to coherence, student learning. At the same time being a limitation of this study, a more structured methodological approach should be developed when continuing in bringing these aspects together. Despite the teacher playing a central role in constructing the scientific storyline,

from a dialogic perspective it is important to bring student ideas and voice to this process. In this study, we have shown different ways to engage students in the linking-making process. Overall we think that this paper shows that the theoretical elements brought to play here could bring new insights into the analysis of classroom discourse. Furthermore, we feel that the relationships suggested by our analysis among pedagogical link-making and communicative approaches with coherence could be useful for teacher trainers addressing how language use is connected to effective learning.

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ORCID

Sami Lehesvuori http://orcid.org/0000-0003-3889-5279
Jaume Ametller http://orcid.org/0000-0002-9289-6718

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