2023: 1

doi: 10.1234/educare.2023.1.752

Analysing interaction in science classrooms – a comparative study of two discourse analysis frameworks

Kristina Danielsson

https://orcid.org/0000-0002-4842-7869

kristina.danielsson@su.se

Ewa Bergh Nestlog

https://orcid.org/0000-0002-3863-6122

ewa.bergh.nestlog@lnu.se

Fredrik Jeppsson

https://orcid.org/0000-0001-6787-7788

fredrik.jeppsson@liu.se

Kok-Sing Tang

https://orcid.org/0000-0002-2764-539X

kok-sing.tang@curtin.edu.au

One central issue for research in classrooms is to provide insights concerning characteristics of classroom interaction that can help teachers improve their teaching. In the present study, we analyse spoken interaction in one elementary physics classroom by the use of two different frameworks, targeting similar aspects of communication, namely how discourse patterns shape the relations between participants. The two frameworks utilized are on the one hand an analysis of the communicative approach according to

Mortimer and Scott, combined with an analysis of discourse patterns such as initiation-response-evaluation (IRE), and on the other hand analysis related to the interpersonal meta-function in Halliday's systemic functional grammar (SFG). The aim was to highlight possibilities and limitations of the different frameworks. Our analyses reveal that the two analytical frameworks have partly the same, partly different affordances concerning what they can reveal about classroom interaction. The analysis of the communicative approach has the potential of elucidating discursive patterns and power relations at a general level, while the analysis based on SFG can provide more details about, e.g., the power relations in terms of how the participants actually structure their utterances. The results are also discussed regarding implications for education.

Keywords: Classroom discourse, Communicative approach, Science education, Speech functions, Systemic functional linguistics

1. Introduction

A central resource for meaning making in science classrooms – as in any disciplinary area – is *talk*: teachers introduce and elaborate on new content and models, make comments while performing demonstrations, instruct students before practical work, and discuss science issues of importance for society with their students, and so forth. The students on their side are part of whole class-discussions and they engage in small group discussions. The teacher orchestrates these activities, and interacts with students in different ways. Hence, analysis of the spoken classroom interaction is one central issue for educational research in all subject areas.

Concerning the ways in which talk in classrooms come into play, the analytical framework used as the lens to study the talk greatly influences the interpretation researchers can make of the talk. In science education, a substantial amount of research has been based on analysis of different communicative approaches suggested by Mortimer and Scott (2003), resulting in a broad categorisation of science classroom talk as authoritative, dialogic, interactive, and non-interactive (e.g., Buty and Mortimer 2008; Cavalcanti Neto, Ribeiro de Amaral, and Mortimer 2018; Scott, Mortimer, and Aguiar 2008). Through this case study, however, we compare that framework with an analysis of interaction according to Halliday's systemic functional grammar (SFG) (Halliday and Matthiessen 2014), in order to highlight the possibilities and constraints with each of them. The frameworks were developed with different foci and within different academic disciplines. The point of departure of Mortimer and Scott (2013) is science education, and they specifically aim at

describing the discursive practices in such settings. The point of departure for SFG, on the other hand, is language and how language is used to fulfil specific purposes in different practices.

In the present case study, based on a lesson comprising different classroom activities with different teaching purposes (cf. Mortimer and Scott, 2003), we analyse spoken communication in one science classroom, utilizing analyses of communicative approaches in Mortimer and Scott's framework (Mortimer and Scott 2003, 25) together with central aspects of the interpersonal metafunction in SFG, namely speech functions (Halliday and Matthiessen 2014). Both frameworks target similar aspects of spoken interaction, namely how the interaction patterns mirror, for instance, power relations between the participants, for instance in regard to who is allowed, or expected, to take the interaction forward, or to question or challenge other participants in the communicative situation. With this study, we aim at analysing classroom interaction through the lenses of the two frameworks, and to discuss the benefits of them. We are guided by the following research questions:

> How can the classroom interaction be described through the two frameworks?
> What are the possibilities and limitations of the two frameworks for analysing classroom interaction?

2. Analytical tools in previous research on interaction in classroom discourse

Classroom discourse has been a major area of interest in science education since the 1990s with Lemke's seminal work on how classroom activities and scientific knowledge are constructed (Lemke 1990). Although many of the processes involved in classroom discourse are similar across disciplinary areas, science classrooms, the focus of the present study, stand out as unique research sites due to the distinctive epistemological nature of science (Tan and Tang 2019). One of the major issues identified from early research in this area is the tension between a dialogic and authoritative stance (cf. Mortimer and Scott 2003). Largely due to the emphasis in mastering scientific content, the discourse in science classrooms has been described as typically driven by an authoritative stance focusing on a narrow range of accepted answers (Lemke 1990; Mehan 1979). At the same time, there has been much effort and emphasis to promote a dialogic discourse by encouraging more students' voices in the interaction (Chin 2006; Kelly 2007; Lee 2007). This emphasis on dialogic discourse is further supported by recent calls to integrate socioscientific issues and argumentation in science education (Bossér and Lindahl 2019; Knain 2015).

As mentioned, one common approach for analysing discourse in science classrooms is the analytical framework developed by Mortimer and Scott (2003) to categorise talk into four different communicative approaches describing how teachers interact with students and accommodate different points of view. These four approaches are: interactive–dialogic, non-interactive–dialogic, interactive–authoritative, and non-interactive–authoritative. In their overall analytical framework, Mortimer and Scott also include 'patterns of discourse' in terms of, for instance, the authoritative IRE-pattern (initiation–response–evaluation) (Mehan 1979). Such analyses can be related to another approach commonly adopted for analysis of communication in science classrooms, namely the application of a microanalytic coding scheme influenced by speech act theory and conversation analysis. Similar analytic systems are also found in other studies in science and mathematics education (e.g., Chin 2006; Kim and Hand 2015; Koole 2010; Tytler and Aranda 2015).

Some previous studies focusing on classroom interaction in general build on the interpersonal metafunction of SFG. Partly drawing on this metafunction, Sinclair and Coulthard (1975) developed an analytic system to describe classroom exchange as a unit consisting of various discourse moves (e.g., initiation, response, follow-up) and acts (e.g., question, answer, statement, request, offer, acknowledge, accept, reject). Rose (2018) presents a comprehensive framework for analysing pedagogic registers describing exchange structures in terms of primary and secondary roles, with teachers' evaluations termed as 'delayed primary roles'[1] (Rose 2018, 4f; Thwaite, Jones, and Simpson 2020). Thwaite et al. (2020) relate to the interpersonal metafunction when analysing speech functions (SFG) and to exchange and knowledge structures, with reference to Martin and Rose (2007). Llinares, Morton and Whittaker (2012) combine Mortimer's and Scott's framework with SFL, though without taking speech functions into account. Concerning the interpersonal metafunction, they instead use the framework of 'appraisal' (Martin and White 2005).

Hence, both frameworks compared in the present study have at least to some extent been used to categorise talk in science classrooms, though systematic comparisons of the two are rare. Knain (2015) gives a short example from a classroom dialogue where he analyses speech functions according to SFG and relates the analysis to the common IRE-pattern, though without problematizing or discussing the possibilities and limitations of the two frameworks for analysing

[1] In such exchanges, the teacher is the 'primary knower' (K1) while the student is the 'secondary knower' (K2).

classroom interaction. In the present study, we have synthesized communicative approaches and discourse patterns with analyses of speech roles and speech functions according to SFG for more in-depth analyses, with the aim to uncover the benefits of the two frameworks.

3. Theory and Analytical Perspectives

The framework for analysing *communicative approaches* in classroom interaction developed by Mortimer and Scott (2003) is based upon empirical data from classroom studies, and their research is grounded in sociocultural theory. In particular, they highlight that meaning-making is 'a dialogic process, where different ideas are brought together and worked upon' (2003, 3)[2]. Their framework relates to different aspects of teaching, for instance concerning the content that comes into play and how the communication is structured and acted out. Our analyses mainly concern communicative approaches and patterns of discourse as these aspects target similar aspects as speech roles and speech functions according to SFG.

Mortimer and Scott claim that 'the concept of communicative approach is central to [their] framework, in providing a perspective on how the teacher works with the students to develop ideas in the classroom' (2003, 33). They describe and categorise teachers' talk with students in the science classroom along two dimensions. The first dimension concerns a continuum of dialogicity versus authoritativeness and describes whether different ideas or perspectives come into play and are explored (dialogic discourse) or if one perspective appears to count as the only, or the most adequate perspective (authoritative discourse). The second dimension concerns a continuum of interactive versus non-interactive talk and concerns to what extent several participants (usually the teacher and several students) are taking part (interactive talk) or if only one person (usually the teacher) is the one who talks (non-interactive talk) [3].

[2] Even though Mortimer and Scott (2003) refer to Bakhtin (e.g., 1986), their use of 'dialogic' is narrower.
[3] Mortimer and Scott present both of these the dimensions as continua (2003), though in practice, the interaction would, for instance, be predominantly interactive or non-interactive.

These two dimensions constitute the four classes mentioned above:

> A. *interactive–dialogic*: teacher and students explore points of views and ideas, with authentic questions, that is, questions that the teacher does not know the answer to.
>
> B. *non-interactive–dialogic*: the teacher presents different points of views and ideas,
>
> C. *interactive–authoritative*: the teacher asks questions aiming at guiding the students, typically towards a school science perspective,
>
> D. *non-interactive–authoritative*: the teacher presents one specific perspective, typically a school science perspective. (Mortimer and Scott 2003, 35)

Mortimer and Scott consider none of these approaches to be superior to the others, but instead claim that each of them has its benefits and can be employed in different parts of a teaching and learning sequence, depending on focus and aim.

When dealing with scientific content, there is often an underlying 'scientific story' (e.g., Mortimer and Scott 2003) that the teacher wants the students to learn. Therefore, as mentioned, an authoritative approach might be expected. However, in such contexts, dialogic sequences can be one way of exploring and working on students' views (i.e., one of six 'teaching purposes' suggested by Mortimer and Scott (2003).

Mortimer and Scott (2003) regard patterns of discourse as one aspect of how the communicative approach is acted out. One common discourse pattern in classrooms is the authoritative triadic pattern of initiation-response-evaluation, IRE (Mehan 1979), which builds on a teacher initiation (I), often through a (non-authentic) question, followed by a student response (R) which is then evaluated (E) by the teacher. Patterns involving feedback (F) from the teacher with an aim to encourage the student to elaborate on an answer (Mortimer and Scott 2003; Scott et al. 2006)[4] on the other hand, indicate dialogic interaction. Hence, IRE- and IRF-patterns are evidence of the two different interactive classes of communicative approach: class C and A respectively, as above.

The other analytical framework concerns *speech roles and speech functions*, which are related to the interpersonal metafunction in SFG, which in turn is framed by a social semiotic perspective (Halliday 1978; Halliday and Matthiessen 2014). According to the SFG theory, human

[4] In Scott et al. (2006), 'prompt', rather than 'feedback' is used, while Cavalcanti Neto et al. (2018) use both prompt and feedback; in our analyses, we use 'feedback' F.

communication always relates to, and accommodates, three main metafunctions: the interpersonal, ideational, and textual metafunction. In classroom interaction, the participants interact and enact their relation with others (interpersonal metafunction) and their ideas about a disciplinary content (ideational metafunction), which is formed in utterances structured in specific ways (textual metafunction). In the present study, we focus on the interpersonal metafunction only. From a functional perspective of communication, it can be particularly relevant to focus on that metafunction: in, for instance, spoken interaction, the linguistic choices for saying things are made in relation to the purpose of interacting with the other part in the communicative situation.

According to SFG theory, in any communicative exchange, there are two fundamental communicative purposes, namely giving and demanding, where speakers can give or demand either information or 'goods and services'[5], resulting in four speech roles: 1a) giving goods and services, 1b) giving information, 2a) demanding goods and services, and 2b) demanding information. These four speech roles are expressed through the following speech functions: 1a) offer, 1b) statement, 2a) command, and 2b) question (see Table 1 for an overview).

Table 1: Four basic speech functions: offer, statement, command, and question, connected to speech roles (congruently expressed grammatical choices given in parenthesis[6]) (cf. Halliday and Matthiessen 2014, p. 136; Knain 2015, p. 32)

Speech role	**a) goods and services**	**b) information**
1. giving	offer "Would you like me to close the window?" (interrogative) "I can close the window for you." (declarative) "Tell me if you want me to close the window!" (imperative)[7]	statement "It's cold in here." "I will close the window." (declarative)
2. demanding	command "Shut the window!" (imperative)	question "Can you close the window?" (interrogative)

In communicative situations, a speaker can initiate a topic through an *action move*, for example by giving or demanding information, while the other speaker reacts to the former action move

[5] Goods can be any physical thing and services can be different kinds of favours. A service could be, for instance, an offer to act in favour of someone else (see Table 1).
[6] Speech functions can also be expressed non-congruently, see below.
[7] In contrast to the other speech functions, there is no specific congruent grammar for offers.

through a *response move*, for example by acknowledging the given information or by giving the requested information (see Table 2). Hence, an action move implies that some kind of response move is to follow. Both action moves and response moves can be expressed non-linguistically, for instance through gesture, action, or gaze. Examples from classrooms are when the teacher points, or looks at a student to demand information, or when students act in response to a demand for service from the teacher. Response moves can also be given through discretionary alternatives, for instance refusal to undertake action as a response to a command, or to challenge instead of answering a question (see Table 2).

Table 2: Expected response moves and discretionary alternatives (based on Thompson 2014, 85)

	Action move	**Response move**	
Speech roles	**Speech function**	**Expected response**	**Discretionary alternative**
Give goods & services	offer	acceptance	rejection
Demand goods & services	command	undertaking (action)	refusal
Give information	statement	acknowledgement	contradiction
Demand information	question	answer	challenge

In Table 1, congruently expressed grammatical choices for each of the four speech functions were given. However, speech functions can also be expressed non-congruently (cf. interpersonal metaphor, Halliday and Matthiessen, 2014; Thompson, 2014, 246ff). The following three utterances are examples of action moves with the function 'demand service', in this case, to persuade students to close their books. Hence, the speech function is a command, but the grammar differs, and only the first utterance is expressed congruently (imperative) (cf. Table 1):

- Close your books! (imperative)
- Everyone will close his or her book. (declarative)
- Can you close your books?[8] (interrogative)

[8] Most people would add a please, to these examples, but to make it grammatically clear we stick to these expressions.

The second and the third expressions are non-congruent. Thus, from a grammatical point of view, the speaker does not actually mean what she says. However, it is worth noting that in this case, a non-congruent expression is actually expected, since an imperative would be considered impolite in most social situations. Nevertheless, using non-congruent expressions in classroom communication can at times be risky, since such expressions might lead to misunderstandings among the students.

4. Methods

4.1 Data and participants

Data was collected within an interdisciplinary research project financed by the Swedish Research Council (registration no. 2017-03478) where the research group followed the teaching and learning activities in two primary classrooms when students worked with shadow and light. Three cameras were used to collect video data in the classrooms: one following the teacher, one giving an overview of the whole class and one focusing on a student group consisting of three students. However, in the present study, examples from group interaction were taken from another student group, since the pupils in the focus group did not interact much with each other during that activity. Audio recordings were used to catch spoken interaction that might not be taken up by the video cameras. Furthermore, notes on the whiteboard were photographed, and texts used or produced in the classroom were collected. The dataset used in the present study comprises video, and audio recordings from one lesson held by Lisbeth who was specialised in science education. The class consisted of 22 students of mixed genders, aged 10–11 years. Lisbeth's class was chosen since she was the most experienced of the two teachers. Therefore, she could be expected to have developed a competence in classroom interaction. The lesson comprises four activities – both whole class teaching and students' group work. It was presumed that if the interaction patterns would differ depending on activity, this lesson would be suitable for capturing such potential differences. Also, an overall impression was that this lesson was also representative for the teaching sequence as a whole. This lesson was the first one in a theme about light. The communication in the classroom was in Swedish. The project was approved by the Swedish Ethical Review Authority (2019-02715) and adheres to their guidelines concerning ethical considerations such as informed consent, anonymity and the right to withdraw the consent without giving a reason for. All names in the article are fictitious to maintain the participants' anonymity. At times Student is used, when we could not identify the student.

4.2 Analytical Methods

As a first step, the video recordings were transcribed mainly concerning the spoken communication, with comments on other resources, such as gestures, writing and artefacts used during hands on-activities. Three of the researchers in the team, all native speakers of Swedish, made the transcription. It was then translated into English to enable joint analysis with the fourth member of the research team. In the translations, the aim was to maintain the lexico-grammatical choices, sometimes resulting in slightly non-idiomatic English. In the examples used in the results section, the team also took into consideration prosodic aspects, such as intonation, when deciding, for instance, speech functions.

Transcription key:

- . (after space): pause, with number of dots indicating pause length, e.g. "Eh . from the lamp and the strip lights" (short pause); "Reflect means like … how shall?" (longer pause)
- Italics: stressed word, e.g. "Yes, it's *your* turn now."
- (--): inaudible
- /…/: omitted sequence

As a second step, the activities that built up the lesson were identified. Activities are broad timescale events determined by the teacher's instructional focus (cf. teaching purpose, Mortimer and Scott 2003). Activities could, for example, be an introduction to a lesson or students' hands-on activities. The students' attention is drawn towards a dominant resource in an activity, for instance, the teacher with her actions during an introduction, or a worksheet along with hands-on material during investigations. The content during the identified activities was then related to six teaching purposes (that is, what the teacher might be trying to achieve) suggested by Mortimer and Scott (2003, 28f), namely: i) opening up the problem, ii) exploring and working on students' views, iii) introducing and developing the scientific story, iv) guiding students to work with scientific meaning, and supporting internalization, iv) guiding students to apply, and expand on the use of, the scientific story, and handling over responsibility for its use, and vi) maintaining the development of the scientific story.

As a third step, transcriptions were analysed concerning i) communicative approach, including the discourse patterns (e.g., IRE- or IRF-sequences), and ii) speech roles and speech functions. One note regarding the analysis of speech roles and speech functions: in classroom triads, the teacher's third move is considered a response to the student's response (cf. delayed response in Rose, 2018). The teacher's response can then be given through a question:

> T: Are shadows longer at noon or in the afternoon?
> S: In the afternoon.
> T: How come the shadows are longer in the afternoon? (Acknowledgement; Response move: give information/Action move: demand information).

In the above example we consider the teacher's response to be a response move where the teacher gives information, acknowledging that the student's response is correct. The reason why we consider this to be an acknowledgement is mainly based on structure, where the expression 'how come' followed by a factual statement presupposes that the statement is true. At the same time, the question is an action move, demanding more information, hence analysed as two speech roles and speech functions. The teacher could have chosen a slightly different wording when responding to a student's (in this case incorrect) answer:

> T: Are shadows longer at noon or in the afternoon?
> S: At noon.
> T: Why do you think that shadows are longer in the afternoon? ([Challenge][9]; Response move: give information/Action move: demand information).

In this case, the structure of the teacher's response does not presuppose that the statement, 'shadows are longer in the afternoon', is true. Therefore, the response move (give information) is analysed as the discretionary alternative challenge. Note that according to Table 2, however, a challenge would rather be a discretionary alternative following a question (demand information) but as the above example indicates, one way of making students clarify – or develop – their answers is by challenging them.

5. Results

[9] In our analyses, discretionary alternatives (see Table 2) are given in square brackets.

Four activities were identified in the lesson: 1) Introduction, 2) Mutual reading and text talk, 3) Hands-on activity, and 4) Summing up (Table 3). The dominant resource during Activity 1 and 4 was that of the teacher and her actions. During Activity 2, the dominant resource was the textbook from which the students took turns reading aloud (with the teacher offering specific students to do so), and during Activity 3, the dominant resource was a worksheet and hands on-material.

Table 3: Activities during the lesson, with teaching purpose (cf. Mortimer and Scott 2003)

Time spent*	**Activities during the lesson**	**Dominant resource**
7 min.	Activity 1: Introduction to physics and light (where does light come from?) Teaching purpose: = opening up the problem (light sources).	Teacher
10 min. 30 sec.	Activity 2: Mutual reading and text talk Teaching purpose: = opening up the problem (light source/reflection).	Textbook
19 min.	Activity 3: Hands-on activity in small groups Teaching purpose: working on students' views (shadow formation)	Worksheet and hands-on material
4 min.	Activity 4: Summing up Teaching purpose: working on students' views (shadow formation)	Teacher

Concerning the teaching purposes suggested by Mortimer and Scott (2003), the main teaching purpose during activity 1 could be regarded as opening up the problem. The same could be said about activity 2. However, as will be shown below, during activity 2, the concept 'reflection' appears to engage the students, when one student brings it up as a 'difficult word'. Activity 3, a hands-on activity with students creating shadows and answering questions in a worksheet, and activity 4, the follow-up of that activity, could both be considered exploring and working on students' views, in this case 'shadow formation'.

In the following, we present the results of the analysis of on the one hand communicative approach and on the other hand speech roles and speech functions during the four activities. The presentation of the results is illustrated by examples of the identified interaction patterns in the respective activity. These are first analysed concerning the communicative approach including

discourse patterns, and then concerning speech roles and speech functions. Finally, a comment on the teaching purpose of the activity is made. The utterances in the examples presented in tables are numbered consecutively within each activity, with examples from activity 1 numbered 1.1, 1.2, 1.3, etc., and examples from activity 2 numbered 2.1, 2.2, 2.3, etc. Two examples are given from activity 1 and activity 3.

5.1 Where Does the Light Come from? Eliciting Students' Ideas about Light (Activity 1)

During the first activity, *Introduction,* the teacher briefly presented the content area ('we are going to talk about light'). She then elicited different kinds of light sources from the students and eventually wrote down some examples on the whiteboard.

The communicative approach at the very start of this activity was characterized by a number of turns with IRFRF discourse patterns. Example 1a is such an example. It was taken from the start of the introduction, when the teacher introduced the content area 'light'. She initiated the interaction by saying that they are going to work with 'light', then saying that 'it's pretty bright in here', connecting to the students' everyday experiences (I). IRFRF discourse patterns would be evidence of dialogic interaction according to Mortimer and Scott (2003). However, in this case the interaction concerned everyday experiences (e.g., number of lamps at home or in the classroom), and the questions posed to the students did not really contribute to exploring or working on their views regarding 'the scientific story' related to light.

Example 1a: 'Where does the light come from?'

Line	**Utterance**	**Analysis**
1.1	**Teacher:** We are going to talk about light. Right now it's pretty bright in here.	I 2 Statements (action move: give information)
1.2	**Student**: It's so much brighter at home.	R [Contradiction] (response move: give information)
1.3	**Teacher**: How come it's so much brighter at home then?	F Acknowledgement (response move: give information) Question/ (action move: demand information)
1.4	**Student:** We have more lamps	R Answer (response move: give information)
1.5	**Teacher**: Have you got more lamps there?	F [Challenge] (response move: give information) Question (action move: demand information)
1.6	**Student**: Yeah. And much stronger lamps, much stronger lamps.	R Answer (response move: give information)
1.7	**Student:** (counting lamps) 1, 2, 3. In here there are only nine.	R Answer (response move: give information)

Third column shows 1) I: initiation, R: response, E: evaluation, 2) speech function with first letter in uppercase, 3) speech role in brackets ( ), and 4) discretionary alternative in square brackets [ ][10]

Concerning speech roles and speech functions in Example 1a, action moves were uttered by the teacher, while students were mostly making response moves. Interestingly, the first response move made by a student (line 1.2) was actually a contradiction of the teacher's first action move: the statement that it was bright in the classroom. This contradictive statement was acknowledged by the teacher (line 1.3), accepting the student's statement that it is brighter at home. At the same time, it was taken up with a new action move, demanding more information through a question: 'How come…?'. A couple of turns then followed, with the teacher in new action moves asking questions, in line 1.5 by turning the student's response into a new question, this time challenging the student. Hence, in different ways, the teacher turned the students' response moves into action moves to demand more information.

We now turn to Example 1b, which is more typical of the interaction during the rest of Activity 1. Here, the communicative approach is characterized by authoritative IRE-chains. Example 1b is a direct continuation of the interaction shown in Example 1a. The teacher then initiated (I) the interaction by asking where the light comes from, trying to elicit examples of light sources, with students providing short responses (R), followed by the teacher's evaluation (E). As Example 1b shows, in her evaluations, the teacher at times repeated the student's response with an affirmative intonation, hence showing that the answer was satisfying, then prompting other students to contribute through new initiations (I) (e.g., Example 1b, line 1.10–1.11).

[10] Regarding speech functions in the examples, for action moves, we indicate the four typical speech functions (offer, statement, command, and question), for response moves, we indicate either expected response or discretionary alternatives according to Table 2.

Example 1b: 'Where does the light come from?'

Line	Utterance	Analysis
1.8	**Teacher:** In here, where does the light come from when we are here in the classroom? Where does the light come from then?	I 2 Questions: (action move: demand information)
1.9	**Student**: The lamp.	R Answer (response move: give information)
1.10	**Teacher**: The lamp. (affirmative intonation)	E Acknowledgement (response move: give information)
1.11	**Teacher:** Where does the light come from? Ingvar.	I Question (action move: demand information) (action move: offer service, i.e. inviting Ingvar to participate)
1.12	**Ingvar**: Eh . from the lamp and the strip lights.	R Answer (response move: give information)
1.13	**Teacher**: From the lamp and the strip lights.	E Acknowledgement (response move: give information)

* Third column shows 1) I: initiation, R: response, E: evaluation, 2) speech function with first letter in uppercase and 3) speech role in brackets ( ).

In regard to speech roles and speech functions in Example 1b and, in fact, throughout the activity, action moves were generally uttered by the teacher, while students were mostly making response moves. The students' response moves normally resulted in new responses from the teacher in the form of expected responses, in Example 1b in the form of acknowledgments (e.g., line 1.9–1.10 and 1.12–1.13), followed by action moves demanding information from the students (e.g., line 1.11). In contrast to the interaction shown in Example 1a, no discretionary alternatives were made during the IRE-sequences, for example in the interaction shown in Example 1b.

As mentioned above (table 3), the teaching purpose of this activity could be regarded 'Opening up the problem' (Mortimer and Scott 2003, 29), however in quite a superficial way rather than actually engaging the students in 'the initial development of the scientific story' (ibid., 29). The students were encouraged to connect to their everyday experiences, though without then connecting these experiences to the scientific story. Examples are the sequences dealing with numbers of lamps and relative brightness at home and at school, and the sequences aiming at eliciting light sources from the students. Hence, the activity might not contribute to the initial development of the scientific story.

5.2 What is Meant by Reflection? Sorting out Difficult Words in the Textbook (Activity 2)

At the beginning of Activity 2, *Mutual reading and text talk*, the teacher asked the students to open their books, and the students then took turns reading aloud from a section on light and light sources, followed by a discussion about 'difficult words'.

The communicative approach during this activity was characterized by an interactive and authoritative interaction based on IRE-patterns. Example 2 shows a sequence of the interaction when the students had just finished their reading, when the teacher asked them whether they had found any words difficult. One student said 'reflection' and a number of turns followed, with the triadic IRE-pattern, starting with the teacher's initiation (I): 'Reflect. What does that mean?' and the invitation to Tomas to respond (line 2.1). During Tomas' response, the teacher gave a number of back-up signals, such as 'mm', said with a flat tone, with Tomas continuing his response. The teacher then gave Tomas a final positive evaluation (E) through a 'mm' (line 2.5) uttered with an assertive, rising, tone. The interaction pattern was then similar throughout the discussion. Several students contributed with responses (R), usually after being prompted to do so, but also by taking the turn (e.g., Eskil, line 2.3). The teacher typically evaluated responses with a short 'mm' (with a flat intonation, which we interpret as a prompt for the student to continue) or, based on the intonation, an affirmative 'yes', further enhancing the authoritative IRE-pattern.

Example 2: 'What is meant by reflection?' *

Line	Utterance	Analysis
2.1	**Teacher**: Reflect, what does that mean then Tomas?	I Question (action move: demand information)
2.2	**Tomas**: Reflect means like … how shall? . I know what it means but (said quickly). Sort of if I'm outside in the sun (T: mm, flat intonation) like if there is a glass . if there is a mirror in the sun . like .. if I put the mirror . then it'll reflect.	R Answer (response move: give information)
	(Inaudible: Several students speak at the same time)	
2.3	**Eskil** (without having been invited to talk): You can see the sun (interrupts himself)	R Answer (response move: give information)
2.4	**Tomas**: That's what reflect means.	R, continued Answer (response move: give information)
2.5	**Teacher**: mm (rising, affirmative, intonation)	E Acknowledgement (response move: give information)

*Third column shows 1) I: initiation, R: response, E: evaluation, 2) speech function with first letter in uppercase and 3) speech role in brackets ( ).

Concerning speech roles and speech functions, similar to the pattern in Example 1a and 1b, during this activity, action moves demanding information were generally uttered by the teacher, while students mostly made response moves, giving information, with the teacher finally acknowledging the students' responses. During this activity, no discretionary alternatives were noted (cf. Example 1a, where discretionary alternatives were uttered both by the teacher and by one of the students).

Concerning teaching purpose, this activity could be regarded a continuation of 'Opening up the problem' regarding light sources, though what appeared to engage the students to a greater extent was the concept reflection, which was a word in the text that they found difficult and which a

number or students attempted to explain. Hence, the activity had potential to contribute to the initial development of the scientific story concerning how light travels in a continuum.

5.3 Why does a Shadow Appear? Hands on Activity in Small Groups (Activity 3)

Activity 3, *Hands-on activity*, was based on a worksheet instructing the students to first create shadows with flashlights and their hands, and then to answer the questions 'Why does it become a shadow?' and 'Why does not a shadow appear?'. A final task was to 'Draw an image to explain why shadows are formed'. The students worked in small groups and the teacher circled around the classroom and did check-ups in the groups. However, as most of the interaction during this activity was between the students, we have chosen to comment on a couple of examples taken from such interaction.

In Example 3a, the students took turns using a flashlight to create shadows on the wall with their hands, for instance to make animals. They commented on their actions and invited each other to use the flashlight. The communicative approach then was mainly interactive and authoritative. In Example 3a, it is authoritative in relation to what is to be done rather in relation to science. When creating shadows, one student typically initiated the interaction, for instance by telling a peer that it was her turn (e.g., line 3.1) or by asking a peer how to make a specific shadow (line 3.4) (I). Such initiatives were often followed by a response (R) from the peer, through action and words (3.4–3.6), or through words only (3.2). Patterns including evaluations or feedback were rare. Hence, a common pattern was chains of IRR. One exception is shown in line 3.7, where Student 1, who appears to have taken charge, evaluated the shadow that her peer had made: 'But it doesn't look like a dog' (E).

Example 3a: Creating shadows*

Line	**Utterance**	**Analysis**
3.1	**Student 1**: It's your turn now. (hands over the flashlight to Student 2) (inaudible comment from another student)	I [[Command: declarative]] (action move: demand service)
3.2	**Student 2:** What? (Student 2 does not take action)	R [Undertaking action by questioning] (response move by action move: demand information)
3.3	**Student 1**: Yes, it's *your* turn now. (uttered in a commanding tone)	R Acknowledgment (response move: give information) [[Command: declarative]] (action move: demand service)
3.4	**Student 2**: Okay. Hang on. How was it? Like that? (forms a shadow with hands)	R Undertaking action I 2 Questions (action move: demand information)
3.5	**Student 1**: And then the little finger like that. (shows how Student 2 should hold the finger)	R Answer (response move: give information) Offer (action move: give service)
3.6	**Student 2**: Yes. Wait. (forms a shadow with the hands)	R Acknowledgement (response move: give information) Undertaking action (response move: give service)

3.7	**Student 1**: But it doesn't look like a dog	E [Rejection] (response move: give information)
3.8	**Student 2:** No not at all, it looks more like a duck. (students laugh)	R Acknowledgment (response move: give information)

*Third column shows 1) I: initiation, R: response, E: evaluation, 2) speech function with first letter in uppercase, 3) speech role in brackets ( ), 4) discretionary alternative in square brackets [ ], and 5) non-congruent choice in double square brackets [[ ]].

Concerning speech functions and speech roles in Example 3a, the students took turns making action moves and response moves, though student 1 was the one who demanded service, in this case for a peer to form a shadow (in specific ways). When student 2 made an action move, she asked for help from student 1 about how to form the shadow (line 3.4). A couple of discretionary alternatives could be noted, such as not acting as a response to the demand for service (line 3.2) and a rejection as a response to the peer's effort to form a dog-like shadow (line 3.7). A couple of action moves with the function of demanding service (e.g., for a peer to form shadows) uttered by Student 1 were made through statements, hence a non-congruent, polite, choice (line 3.1 and 3.3). However, these statements were combined with action, such as handing over the flashlight, or interventions to show how to form a shadow in the form of a dog. Therefore, even though the wordings were uttered non-congruently with the possibility for the other part not to act, the accompanying actions made them more non-negotiable commands.

Our next example, Example 3b, shows the interaction that took place in the same student group right after the interaction shown in Example 3a. The students then started discussing how to formulate an answer to the first question in the worksheet, 'Why does it become a shadow?' Example 3b illustrates that the communicative approach between the students at times was then interactive and dialogic in regard to science content, for example when the students negotiated with each other about how to answer a question in the worksheet (line 3.10–3.12). However, in the example, student 1 took an authoritative position regarding the working process. Again, student 1 made an initiative (I) and then a peer responded (R) (e.g., 3.9–3.10, 3.13–3.14). In Example 3b we can also see an evident pattern that was typical for the activity, namely that students

contributed with a number of responses after the initiation (including the student who made the initiative) without being asked to do so (e.g., 3.9–3.12).

Example 3b Responding to worksheet questions*

Line	**Utterance**	**Analysis**
3.9	**Student 1:** And then: Why does it become a shadow (reads aloud from the worksheet). You hold (--) No but I don't know. Why does it become a shadow?	I Statement (action move: give information) Question (action move: demand information)
3.10	**Student 2**: When the light cannot get in (--)	R Answer (response move: give information)
3.11	**Student 1:** The light goes like that .. and then you take the hand. If you take the hand (--). What? I don't understand.	R Answer (response move: give information)
3.12	**Student?:** I understand. No it (--)	R Answer (response move: give information)
3.13	**Student 1**: No, how can we explain?	F Question (action move: demand information)
3.14	**Student?**: and then you place your hand in front of the light (--)	R Answer (response move: give information)
3.15	**Student 1**: Yes. Exactly. So write that down now.	E Acknowledgement (response move: give information) I Command (action move: demand service)

3.16	**Student 2**: Yes what?	R [Refusal] (response move: demand information)
3.17	**Student 1**: Why does it become a shadow? /…/ because you cover the light. Full stop.	R (response move: give information)
3.18	**Student 2**: (writes on the worksheet) Like that.	Undertaking action (response move: give service)

*Third column shows 1) I: initiation, R: response, E: evaluation, F: Feedback 2) speech function with first letter in uppercase, 3) speech role in brackets ( ), 4) discretionary alternative in square brackets [ ].

Concerning speech functions and speech roles in Example 3b, again, the students took turns making action moves and response moves, though Student 1 appeared to be the one who demanded information or service to a large extent, hence acting as an informal leader. Here we can note a congruently expressed command: 'So write that down now' (3.15). This was similar to other instances – not shown in the examples – during text production, when students at times commanded a peer to write down an answer. When forming shadows during the hands-on activity, other congruent commands often concerned how to create shadows, such as 'hold it like this!', or 'keep still!' (not shown in the examples). Again, one of the students refused to give service (3.16), hence a discretionary alternative. Both the refusal to act, and the congruent commands uttered between students reveal that they were quite direct in their peer-interaction.

The teaching purpose of this activity could be analysed as working on students' views (Mortimer and Scott 2003, 29), and in this case, shadow formation. The students had no problems to create shadows, and they obviously knew from previous experience how shadows are formed (or not formed). However, to explain why this was the case was obviously more challenging, hence a possible point of departure for further activities and discussions.

5.4 What did you Write? Summing up Hands on Activity (Activity 4)

In the last activity, *Summing up*, the teacher made a sum-up of the hands on-activity in whole class, prompting the students to tell her what they had responded in their worksheets.

The communicative approach during this activity was authoritative and interactive, even though the teacher started the interaction with the comment 'I'm a bit curious about what you have written about why it became a shadow' (not shown), indicating a dialogic approach with the purpose of exploring students' views. However, after this statement, the interaction was built up by IRE-structures (see Example 4). The teacher prompted (I) students to tell her what they had written (e.g., line 4.1, 4.5, 4.8), and students contributed with their answers (R), (e.g., line 4.2–4.3, 4.6, 4.9) which the teacher then evaluated (E) through repetition (e.g., line 4.4, 4.7, 4.10), sometimes combined with 'mm' or 'yes' (line 4.4). Finally, the teacher evaluated all answers: 'really good explanations' (line 4.10) before doing a similar round concerning the second question from the worksheet. It could be argued that the approach was dialogic as the teacher did not evaluate inadequate views negatively. However, as the students were not encouraged to elaborate on their answers, we do not consider the approach to be dialogic.

Example 4: Summing up the hands-on activity: 'What have you written?' *

4.1	**Teacher**: Nina what have you written?	I Question (action move: demand information)
4.2	**Nina**: Because the light (--)	R Answer (response move: give information)
4.3	**Another student from Nina's group**: reflects	R Answer (response move: give information)
4.4	**Teacher**: Reflects. Because the light reflects. Mm.	E Statement (response move: acknowledgment)
4.5	**Teacher**: Edvin what have you written? /…/	I Question (action move: demand information)
4.6	**Edvin**: Well because you cover the light.	R Answer (response move: give information)
4.7	**Teacher**: You cover the light.	E

		Statement (response move: acknowledgment)
4.8	**Teacher**: Ingvar what did you write? /…/	I Question (action move: demand information)
4.9	**Ingvar**: You need sort of (--) to make a shadow (T: and) pen and hand.	R Answer (response move: give information)
4.10	**Teacher**: pen and hand	E Statement (response move: acknowledgment)
4.11	**Ingvar**: yes	R Statement (response move: acknowledgment)
4.12	**Teacher**: /…/ Really good explanations	E Statement (response move: acknowledgment)

*Third column shows 1) I: initiation, R: response, E: evaluation, F: Feedback 2) speech function with first letter in uppercase, and 3) speech role in brackets ( ).

Concerning speech roles and speech functions, again, action moves were uttered by the teacher, while students made response moves that were acknowledged by the teacher in a new response move, which was generally followed by an action move prompting a new student to contribute (e.g., line 4.1–4.5). In addition, as students had worked in groups, they at times built up a response together, e.g., line 4.2–4.3 where a peer from the same group as Nina, who was prompted by the teacher to respond, contributed to the response, with the teacher then acknowledging their responses. All response moves were the expected ones, and both action moves and response moves were uttered congruently during this activity.

Again, the teaching purpose could be analysed as working on students' views about shadow formation. However, even though the teacher's questions were authentic in the sense that she did not try to elicit correct answers, the students were not supposed to elaborate on their answers to develop the scientific story. Instead, she commented on them as 'really good explanations' (line 4.12).

5.5 Summary of the results

In regard to the first research question, our analyses reveal that the two frameworks give similar characteristics of the interaction concerning power relations at an overall level. Regarding interaction patterns, the analysis reveals that on the whole, apart from the hands on-activity, the interaction was driven by the teacher: she was the one who initiated (I) the interaction, while the students gave responses (R), which were then evaluated (E) by the teacher (Example 1a, 1b, 2, and 4), or, at times, subject to feedback (F) (Example 1a). This pattern is mirrored in action moves and response moves according to the analysis of speech roles and speech function, where it is important to note that the teacher's response moves were mainly evaluations of the students' responses (cf. delayed primary role according to Rose 2018). Hence, both frameworks indicate that the teacher had the power to decide who was allowed or required to speak and when to do it. The students' role, on the other hand, was to provide responses which the teacher evaluated (E) in a response move, or – in a few instances – used as a point of departure for a new action move, asking for further information from the student (F).

The second research question concerned the possibilities and limitations of the two frameworks. Although both frameworks to some extent revealed similar things about the interaction during the lesson, for example concerning power relations, they have slightly different potentials for analysing classroom interaction. An analysis of the communicative approach, including discourse patterns, provide a picture at a macro level of the participation structure and to what extent the students are given opportunities to further elaborate on their answers in IRFRF-chains. However, details about, for instance, what kind of evaluations the teacher gives, or how she supports the students to elaborate on their answers are not given.

The analysis of speech functions on the other hand, can give more details at a micro level, compared to the more macroscopic communicative approach perspective. However, in the analysis of speech functions there is a danger of getting lost in all the details concerning, for instance, different linguistic choices in action moves and response moves. Yet, the detailed analysis did shed light on some interesting aspects of the interaction. One example is that discretionary alternatives appeared to be one way for students to exert power, for instance in the introduction to the lesson when a student challenged the teacher's statement that it was bright in the classroom. During the same sequence, we could also note that the teacher used discretionary alternatives when

challenging students to elaborate on their answers. Hence, an analysis of speech functions can shed light on how the teacher's feedback (F) in IRFRF-chains is structured linguistically. Also, the analysis of speech functions reveals to what extent and when the participants use non-congruent choices, such as giving a command through a statement or a question, hence politer choices than a congruent imperative. In this lesson, non-congruent choices were rare. Exceptions were some commands that were uttered through statements, both by the teacher (not shown in the examples) and between students. However, we noted that in the interaction between students, some congruent commands, as well as discretionary alternatives such as contradictions were uttered, such as refusing to act as a response to a peer's command. These choices indicate a quite direct interaction between students, where politeness does not seem to be important. In that sense, the analysis show that students were able to exert power in relation to each other, both as someone who has the power to give commands and as someone who has the power to refuse to obey a command from a peer.

To sum up, performing interpersonal analysis in regard to speech functions is one way of making more fine-grained analyses of interaction patterns compared to that of analysis of communicative approach. On the other hand, the latter is a relatively straightforward and less cumbersome analytical framework. In addition, the analysis of communicative approach gives the larger picture, making visible triads (IRE) versus more complex patterns (chains of IRFRF). To put it metaphorically, while it is sometimes difficult to 'see the wood for all trees' through interpersonal analysis, if only adopting the analysis of communicative approach, we might miss important and interesting details.

6. Discussion and Conclusions

Even though both frameworks can provide us with important knowledge about classroom interaction, they both need to be combined with some kind of content analysis in order to really be useful for education and research. An example from the present study is when students commented on light sources, connecting to their everyday experiences (Example 1a). The interaction then appeared to be dialogic, though the teacher's feedback (F) rather encouraged the students to further elaborate on these everyday experiences than functioned as a point of departure for exploring and working on students' views, or for developing the scientific story.

Even though we have only analysed one lesson in detail, our results point to a number of topics that have implications for education. As mentioned, concerning the dimension of dialogic and authoritative communication, both of these have their place in science teaching. We have concluded that the interaction during the analysed lesson primarily built on the IRE-pattern, which is typical for authoritative discourse. However, the evaluations were often quite vague, such as 'mm' or repetitions of student responses, regardless of them being correct or not. Likewise, all student ideas during the sum up were evaluated as really good explanations regardless of them being correct or not. In a similar vein, the teacher's feedback in IRFRF-chains did not contribute to guiding the students towards connections between their everyday experiences and scientific story. Concerning the dimension of interactive and non-interactive, the teacher in this classroom is obviously directed towards designing an interactive teaching practice where students have opportunities to speak, while the dimension of dialogic and authoritative might not have the same importance in her teaching design. One implication for education is for teachers to recognize that both an authoritative and a dialogical style has their potential, but whichever style is adopted in different activities, the teacher needs to make sure to actually guide the students towards the scientific story.

The interactive style in this classroom builds on the teacher posing questions that the students respond to. This can be contrasted to a general discourse in science that builds on questions about science phenomena that need to be solved. One way of converging towards such practices is to model teaching and learning activities building on scientific inquiry (Bybee 2006). An inspiration then is to utilize frameworks such as predict, observe, explain (POE) (Kearney 2004; White & Gunstone 1992), encouraging students to pose their own questions related to science phenomena in a fashion that guides them towards the discourse of science rather than adapting to an authoritative classroom discourse of right and wrong. For teachers who are mainly familiar with a discourse style similar to the one in the classroom studied here, it can be challenging to adapt to a practice of inquiry with a dialogic communicative approach. Here, knowledge about speech functions can be helpful. In the present study, we noted that when the discourse at least at a superficial level became more dialogic, the teacher used discretionary alternatives. The discretionary alternative 'contradiction' indicates that the response is not in line with the scientific story (cf. negative evaluation), while 'challenge' opens up for elaborations. As mentioned, 'challenge' is in fact the discretionary alternative to the speech role 'demand information'. However, to challenge students' ideas and responses is an important aspect of dialogic classroom

interaction, and in many classrooms, such as the one studied here, it could be beneficial for the students to take part in such interaction to a greater extent. Yet, it is important then to make sure that the challenges actually encourage students to develop on their answers in ways that connect to science, and perhaps back to the students' everyday experiences in order to strengthen the connection between everyday experiences and science (cf. Nygård Larsson 2018). Another potential to enhance students' development of the scientific story in this classroom would be to give them opportunities to make more action moves, such as making statements and asking questions about the content. From our analyses, it was obvious that shadow formation engaged the students, and by building on that engagement in follow-up activities, the content could have been further elaborated on in ways that promote students' learning.

The study was limited to the spoken interaction in a science classroom. Therefore, further research directed to spoken interaction as well as content and multimodal text structures relevant to communicate within the subject would have potential to generate deeper knowledge of importance for the field.

Acknowledgements

This study was made possible by a grant from the Swedish Research Council. We also want to acknowledge the teacher and the students who willingly took part in the project, and the two anonymous reviewers who gave us constructive feedback on a previous version of the article.

Declaration of interests

There are no competing interests for the authors regarding this manuscript.

References

Bakhtin, M.M. (1986). *Speech Genres and Other Late Essays*, edited by C. Emerson and M. Holquist (translation: V.W. McGee). Texas University Press.

Bossér, U., & Lindahl, M. (2019). Students' positioning in the classroom: a study of teacher-student interactions in a socioscientific issue context. *Research in Science Education, 49*(2), pp. 371–390. Doi: 10.1007/s11165-017-9627-1

Bybee, R. W. (2006). Scientific inquiry and science teaching. In L.B. Flick & L.D. Ledermann (Eds), *Scientific Inquiry and Nature of Science. Implications for Teaching, Learning, and Teacher Education*, pp. 1–14. Springer.

Buty, C., & Mortimer, E.F. (2008). Dialogic/authoritative discourse and modelling in a high school teaching sequence on optics. *International Journal of Science Education*, *30*(12), pp. 1635–1660. Doi: 10.1080/09500690701466280

Cavalcanti Neto, A.L., Ribeiro do Amaral, E.M., & Mortimer, E.F. (2018). Analyzing discursive interactions in science classrooms to characterize teaching strategies adopted by teachers in lessons on environmental themes. In K.-S. Tang & K. Danielsson (Eds), *Global Developments in Literacy Research for Science Education,* pp. 149–166. Springer.

Chin, C. (2006). Classroom interaction in science: Teacher questioning and feedback to students' responses. *International Journal of Science Education, 28*(11), pp. 1315–1346. Doi: 10.1080/09500690600621100

Halliday, M.A.K. (1978). *Language as Social Semiotic. The Social Interpretation of Language and Meaning.* Edward Arnold.

Halliday, M.A.K., & Matthiessen, C. (2014). *Halliday's Introduction to Functional Grammar* (4th ed.). Routledge.

Kearney, M. (2004). Classroom use of multimedia-supported Predict–Observe–Explain tasks in a social constructivist learning environment. *Research in Science Education, 34*, pp. 427–453. Doi: 10.1007/s11165-004-8795-y

Kelly, G. J. (2007). Discourse in science classrooms. In S. K. Abell and N. G. Lederman (Eds), *Handbook of Research on Science Education,* pp. 443–469. Lawrence Erlbaum Associates.

Kim, S., & Hand, B. (2015). An analysis of argumentation discourse patterns in elementary teachers' science classroom discussions. *Journal of Science Teacher Education, 26*(3), pp. 221–236. Doi:10.1007/s10972-014-9416-x

Koole, T. (2010). Displays of epistemic access: Student responses to teacher explanations. *Research on Language and Social Interaction*, *43*(2), pp. 183-209. Doi: 10.1080/08351811003737846

Knain, E. (2015). *Scientific Literacy for Participation: a Systemic Functional Approach to Analysis of School Science Discourses*: Sense Publishers.

Lee, Y-A. (2007). Third-turn position in teacher talk: Contingency and the work of teaching. *Journal of Pragmatics, 39*(6), pp. 180–206. Doi: 10.1016/j.pragma.2006.02.004

Lemke, J. L. (1990). *Talking Science: Language, Learning and Values*: Ablex.

Llinares, A., Morton, T., & Whittaker, R. (2012). *The Roles of Language in CLIL*. Cambridge University Press.

Martin, J.R., & Rose, D. (2007). *Working with Discourse: Meaning Beyond the Clause* (2nd ed.). Continuum.

Martin, J.R., & White, P.R.R. (2005). *The Language of Evaluation. Appraisal in English*. Palgrave McMillan.

Mehan, H. (1979). *Learning Lessons: Social Organization in the Classroom*. Harvard University Press.

Mortimer, E., & Scott, P. (2003). *Meaning Making in Secondary Science Classrooms. A Communicative Approach*. Open University Press.

Nygård Larsson, P. (2018). "We're talking about mobility:" Discourse strategies for promoting disciplinary knowledge and language in educational contexts. *Linguistics and Education, 48, pp.* 41–65. Doi: 10.1016/j.linged.2018.10.001

Rose, D. (2018). Pedagogic register analysis: Mapping choices in teaching and learning. *Functional Linguistics, 5*(3), pp. 1–33. Doi: 10.1186/s40554-018-0053-0

Scott, P.H., Mortimer, E. F., & Aguiar, O.G. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *Science Education 90*(4), pp. 605–631. Doi: 10.1002/sce.20131

Sinclair, J., & Coulthard. M. (1975). *Towards an Analysis of Discourse*. Oxford University Press.

Tan, A. L., & Tang, K. S. (2019). The role of dialogue in science epistemic practices. In N. Mercer, R. Wegerif, & L. Major (Eds.), *The Routledge International Handbook of Research on Dialogic Education,* pp. 546–557. Routledge.

Thompson, G. (2014). *Introducing Functional Grammar.* 3rd Ed. Routledge.

Thwaite, A., Jones, P., & Simpson. A. (2020). Enacting dialogic pedagogy in primary literacy classrooms: Insights from systemic functional linguistics. *The Australian Journal of Language and Literacy 43*(1), pp. 33–46. Doi: 10.3316/informit.949635084525088

Tytler, R., & Aranda, G. (2015). Expert teachers' discursive moves in science classroom interactive talk. *International Journal of Science and Mathematics Education, 13*(2), pp. 425–446. Doi: 10.1007/s10763-015-9617-6

White, R., & Gunstone, R. (1992). *Probing Understanding*. The Falmer Press.