Int J of Sci and Math Educ (2015) 13:425–446
DOI 10.1007/s10763-015-9617-6

Expert Teachers' Discursive Moves in Science Classroom Interactive Talk

Russell Tytler · George Aranda

Received: 28 May 2014 / Accepted: 31 December 2014 / Published online: 31 January 2015

Abstract It is well established that teacher-student interactive talk is critically important in supporting students to reason and learn in science. Teachers' discursive moves in responding to student input are keys to developing and supporting a rich vein of interactive discussion. While initiation-response-evaluation (IRE) sequences have been shown to dominate science classroom discourse patterns worldwide, teacher 'prompts' are important for opening up opportunities for reasoning and higher level learning. This paper describes the analysis of video sequences for five expert elementary teachers across three countries to develop a coding scheme for these teachers' 'discursive moves' to guide and respond to student inputs, that unpacks more completely the strategies they use to develop interactive discussion. The analysis showed varied patterns of knowledge transaction, with teacher discursive moves serving three broad purposes: to elicit and acknowledge student responses, to clarify and to extend student ideas. The patterns of talk were also related to the dialogic-authoritative distinction in analysis of talk, to show that this distinction is only clear for particular types of expert practice. While the particular moves teachers use vary across parts of lessons we argue that they are revealing of teachers' particular beliefs and of systemic constraints, and that there exist patterns in the use of the discursive categories that capture how expert teachers build deeper level knowledge in classroom interactive talk. We describe ways in which the analysis can inform science teacher education and the professional learning of teachers of science.

Keywords Expert teachers of science · Video classroom analysis · Elementary school science classroom practice · Interactive classroom talk · Teacher discursive moves · Dialogic-authoritative discourse · Teacher response to student input

Researchers in classroom talk have long noted that traditional science classrooms are dominated by teacher talk with minimal opportunities for students to voice their ideas

R. Tytler (✉) · G. Aranda
School of Education, Deakin University, Pigdons Road, Waurn Ponds, Victoria 3216, Australia
e-mail: tytler@deakin.edu.au

and contribute to the conceptual flow of lessons (Alexander, 2006). A number of studies (e.g. Edwards & Mercer, 1987; Sinclair & Coulthard, 1975) identified the dominant discourse pattern in classrooms as the initiation-response-feedback (IRF, sometimes known as initiation-response-evaluation (IRE)). In this pattern, the teacher asks a question, students answer and receive an evaluative response. This pattern offers limited opportunities for students to engage in elaborated talk, mainly limiting them to short phrases or even one word as contributions to classroom conceptual activity. Yet the role of talk as central to knowledge building in science classrooms has been recognized for many decades now, and since the 1970s, there have been a number of major strands of research that have attempted to understand the role of talk in supporting learning, from a number of theoretical standpoints (Barnes & Todd, 1977; Sinclair & Coulthard, 1975; Edwards & Mercer, 1987; Lemke, 1990; Mortimer & Scott, 2003; Scott, 1998; Alexander, 2006). Analyses of classroom talk have identified the provision of opportunity for students to voice and share ideas as an important component of classroom pedagogical culture that yields higher level conceptual exchanges and leads to more robust learning (Alexander, 2006; Mercer, Dawes, Wegerif & Sams, 2004). It is therefore important for purposes of supporting teacher professional learning to develop evidence-based descriptions of discourse patterns associated with teacher expertise that move beyond prevailing, impoverished discourse traditions.

In this paper, we analyse patterns of discursive moves in classrooms of expert teachers of primary school science to investigate the ways in which these teachers orchestrate whole-class discursive interactions through framing and responding to student input, in ways that move beyond simple IRE patterns. The research aims to identify discursive moves and patterns that are associated with teacher expertise, and in particular, to codify these moves in ways that can inform the professional learning of teachers of science. The research is part of a larger study involving video capture of expert teachers' practice in Taiwan, Germany and Australia. The teachers were selected as experts using a process of peer and science educator recommendation, such that they represent cultural norms of expertise in the three countries.

Theoretical Setting

Analyses of classroom discourse are often framed within Vygotskian notions of the relationship between language and thought (Vygotsky, 1981) in which ideas are held to first appear in the social plane (of the classroom in this case) before they are incorporated in the psychological plane of individual students' thinking. This has been variously interpreted as a need to establish common, or jointly understood knowledge in the classroom (Edwards & Mercer, 1987), as the teacher orchestrating the social construction of knowledge (Driver, Asoko, Leach, Mortimer & Scott 1994; Mortimer & Scott, 2003) or as the need to establish knowledge through exploratory, collaborative exchange of ideas and problem solving (Alexander, 2006; Barnes & Todd, 1977; Mercer et al., 2004). In this research, we adopt a sociocultural perspective (Vygotsky, 1981; Driver et al., 1994) to analyse the means by which expert teachers orchestrate classroom interactions to construct shared meaning.

In performing this analysis, it is important to recognize that classroom talk has an inherent duality, involving authoritative discourse in which teachers guide students to

established knowledge forms, and dialogic or 'internally persuasive' discourse as students grapple with the new meanings opened up by science ideas (Bakhtin, 1981; Scott, 1998). Authoritative or univocal discourse is intended to convey information that is considered fixed, needing to be acknowledged and demanding allegiance. Dialogic discourse is open, treading a line between ideas from others and individual sense making. In dialogic talk, utterances are treated as ideas to be actively questioned, that are mutable and extendable (Scott, 1998).

What are the strategies and discursive moves through which teachers can move beyond the teacher-dominated simple IRE discourse pattern to establish higher levels of shared understanding through talk? A number of researchers have offered analyses of the different moves that teachers make to establish meaning through talk. Edwards and Mercer (1987) suggested a hierarchy of ways teachers exercised control over classroom processes, including cued elicitation of students' ideas involving marking knowledge as significant and joint; paraphrasing students' contributions, offering reconstructive recaps and direct lecturing. Mercer (2004) describes a similar list of techniques to (a) elicit knowledge from learners, using direct and cued elicitations; (b) responding to what learners say, which includes confirmations, repetitions, elaborations and reformulations and (c) describing significant aspects of shared experience, through 'we' statements and literal and reconstructive recaps. Lemke (1990) analyses classroom discourse in terms of two components: an activity structure describing the organizational patterns of interaction, and a 'thematic pattern' of relationships of scientific meaning. He identifies 'thematic development strategies' teachers use, such as: teacher question series consisting of linked IRF exchanges (similar to Mercer's 'cued elicitation') in which teachers might select and modify students answers or elaborate on a student answer to place it within the theme being developed, changing its meaning; joint construction of dialogue, logical exposition, narrative (the telling of stories) and selectively summarizing what has been said.

Scott (1998) and Mortimer & Scott (2003) describe a range of strategies teachers use to develop a teaching narrative. Scott's (1998) analysis of the conceptual line of lessons identified *Shaping Ideas* (through paraphrasing or differentiating between ideas), *Selecting Ideas* and *Marking Key Ideas* as major components, in addition to *Promoting Shared Meaning* (for instance by jointly rehearsing a student's idea in front of the class) and *Checking Student Understanding*. These categories overlap somewhat with the categories of Edwards and Mercer (1987), Mercer (2004) and Lemke (1990).

At a structural level, these analyses of classroom discourse have two frames; the characterization of the teaching sequence structure to build conceptual meaning, and the detailed 'discursive moves' that teachers make to shape and respond to student talk. In each case, there is an overlap between these frames. In the current research, we aim to develop a sharper, evidence-based description of the discursive moves that expert teachers make within a coherent framework of broader purposes that can be productively used to support teacher learning. The effective orchestration of these moves involves a balance between the exercise of authority by the teacher to introduce and establish scientific knowledge at the same time as allowing room for students to explore the meaning of these often new and challenging ideas, in their own language and terms. The dialogic-authoritative distinction gives expression to this duality of purpose, and our analysis will explore whether there are different patterns of discursive moves related to these broader discourse types. Further, given that our teachers represent

expertise as recognized in different cultural contexts, we will explore how patterns of teacher discursive moves are linked to teachers' beliefs and contextual settings.

Our intent in this paper is thus to describe the development of a discursive moves framework, based on lessons of five expert teachers (two from Australia and Germany and one from Taiwan), as one window into the nature of teacher expertise, and the wider implications of this for teacher professional learning and growth. Our intent in this paper does not include cross-cultural comparisons. Rather, the cross-country nature of the four episodes provides us with an opportunity to examine the operation of the framework across a variety of teaching contexts and approaches.

Our research questions are as follows:

1. How do expert teachers of science frame their responses to student input, in interactive classroom talk?
2. How do the patterns of discursive moves relate to the dialogic-authoritative distinction in classroom talk?

Research Methods

This research sits within the EQUALPRIME research project in which we have been analysing, using video capture and analysis, the beliefs, contexts and classroom practices of expert teachers of elementary school science in Australia, Germany and Taiwan. The teachers have been selected as representing expert practice as judged by professional norms in the country. In each country, the local research team sought out teachers with reputations as expert teachers of primary science, both through recommendations of peers and/or experience of teacher educators in working with the teachers in other contexts. In each case, multiple sources were consulted before the teacher was invited to participate in the study. 'Expertise' is thus not characterized in absolute terms or according to conformity to pre-established behaviours, but rather reflects the pedagogical affordances of each country's context of systemic practices and beliefs. That high-level interactive discourse will be found in these classrooms is situated in the study as a hypothesis to be tested, rather than a given determined by methods of selection.

Video sequences of whole topics were generated for each teacher. A method was sought for describing the ways in which teachers managed whole class discussion, in conjunction with small group activity and discussion, to support knowledge building. In particular, we have focused on the way teachers respond to and shape student input into the classroom talk, as a key feature of moving the 'narrative' forward and supporting students' reasoning and conceptual understanding. To take a category from Mercer (2004), how do teachers 'respond to what students say'?

For each teacher, video data on lesson sequences were captured by local research team members. Video capture involved cameras connected to radio frequency microphones to ensure clear audio recordings were attained. One camera followed the teacher throughout the lesson to record how they taught, the resources they used and their interactions with students. The second camera followed a small group of students who were either selected by the teacher, or as a matter of convenience (e.g. they were close

to the student camera). The analysis for this paper involved the teacher camera only. Up to four lessons of each teacher were selected by the local researchers to be shared between the teams involved with the EQUALPRIME project with accompanying information about the school, details about the entire sequence of lessons and transcripts of interviews with the teachers. A series of interviews were conducted with the teachers at the beginning, middle and end of their lesson sequence, as convenient for the researchers and teachers. The initial interview was semi-structured and conducted to gain insight into the teachers' philosophies, experiences and ideas about teaching science. Later interviews involved stimulated recall using video data about recent lessons and were conducted to gain an understanding of how the teachers felt about what they had done and achieved during the lessons and how it fit in with their previously self-identified philosophies and experiences about science teaching. Transcripts of the lessons and interviews from Germany or Taiwan were translated into English.

In the study being reported in this paper, we have analysed video and transcripts of typical sequences of teacher-student interactive talk in four classrooms to categorise the variety of discursive moves made by the teachers in whole-class interactive discussions to work with student inputs. The classrooms involved consisted of year four classes from schools in each of the countries. We chose to work on five teachers: two from Australia (Bob and Colin), one from Taiwan (Mrs. Hong) and a pair of teachers (the KM school teachers) co-teaching in Germany. These teachers were selected to represent variety in teaching setting and approach.

For each teacher, lessons were identified that included substantial whole-class discussion around a conceptual goal, and from these, episodes were selected for coding that represented coherent discussion sequences from distinct parts of the lesson. This meant ignoring episodes of small group exploration or those in which the prime purpose was management of activity. Where it was possible, the episodes were selected for and identified as primarily dialogic, or authoritative in intent. That is, whether the discourse was primarily aimed at opening up students' ideas, or whether it was more focused on establishing agreed scientific ideas (Mortimer & Scott, 2003). Commonly, inquiry-based lesson sequences move from student exploration of ideas in dialogic episodes to authoritative episodes where the teacher shapes students' ideas towards scientific language and concepts (Scott, 1998). The coding was done directly off the video, in Studiocode, in order to capture the intent of the teacher's discursive moves, for which access to gestures, facial expressions and tone of voice, in some cases, were important for coding. With the German and Taiwanese videos, we worked with the transcripts alongside the video.

Development of the Discursive Moves Framework

It was immediately clear that each of these five teachers, who have established reputations for quality teaching, operates in much more sophisticated ways than the simple IRE discourse that has been found to be prevalent in classrooms worldwide. It is also clear that between these teachers, there are significant differences in the nature of the discourse. We used a discourse analysis methodology (Johnstone, 2002) to unpack the meaning and intent of the teachers' discursive moves. We used an event sampling coding approach as distinct from time sampling, with the unit of analysis being a

teacher utterance in response to student verbal input. The coding was performed using Studiocode software. We drew on the video record to make sense of what was being said, including voice modulation and gesture accompanying the talk. While we were aware of the broad categories developed by previous researchers (Lemke, 1990; Mortimer & Scott, 2003; Mercer, 2004), we used a grounded, interpretive approach whereby categories of teacher utterances were developed and refined using an iterative process between two researchers from a systematic analysis of the nature and intent of teacher responses to student input. Each utterance in each of the sequences was assigned to an existing code or assigned a new code as necessary. Where there was disagreement or ambiguity, the researchers discussed this and decided whether the utterance warranted a new category, or pointed to a need for expansion of meaning within an existing category. The coding categories were developed and refined to the point where all teacher utterances in response to student conceptual input fit within the coding system. During this process, the coding categories were grouped into broader categories according to their wider purposes in relation to exploring and shaping student understandings, and these were further discussed and refined as the individual categories settled.

Following the development of the framework, we involved another colleague in discussing and further refining the coding descriptors. We selected a sequence of talk stripped of coding, which was independently coded by the colleague using the coding framework. Further discussion clarified the judgments, the differences between which were often dependent on subtle differences in interpretation of content and teacher intent or on readings of nuanced voice modulation and gestures. Viewing the video clarified the coding in many instances. Subsequently, we selected another sequence of talk stripped of coding, which was independently coded by the two researchers and our third colleague. In this inter-rater reliability exercise, an intra-class correlation was performed between the three raters using SPSS, resulting in a correlation (average measures) of 0.754, indicating a substantial level of agreement between the raters (Landis & Koch, 1977). The coding was most consistent for codes such as Acknowledging (involving the teacher acknowledging a student input without adding judgement, such as saying 'ok' or simply nodding) and Marking (where the teacher draws particular attention to a student utterance by repeating it or highlighting it on the board) but became less consistent for more conceptual codes, which required high-level inferences. An example of the latter distinction is that between requesting confirmation (the teacher using more precise words and asking the student if this is what they meant) and requesting clarification (the teacher requesting further information of the student to tease out the intent of their input). For the coder, the distinction between these hinges on judging the extent of teacher guidance in the interaction designed to achieve more precise meaning. The discussion did not add further to the coding categories or descriptors. We thus resolved that the codes stand as valid representation of teacher purposes, but with inevitable limitations on their reliability because of the interpretive nature of their application in complex exchanges between teachers and students.

In the framework, shown in Table 1, there are 16 distinct categories of teacher discursive moves; 14 of these involving the teacher in directly responding to student input in interactive talk. In the coding window (see Fig. 1) these are separately coded from initial elicitation or 'new' questions that open up lines of inquiry, and student responses that are the other part of the interaction. These response moves fall into three

major categories that represent distinct purposes in shaping student understanding: *Eliciting/acknowledging* student input, *Clarifying* and *Extending* student ideas. There is a further category of *Elaborating* discursive moves that are not direct responses to student input but involve the teacher presenting the science view in an extended response that sits apart from the negotiation of meaning implicit in the discursive moves categories. The coding categories are described in Table 1.

Patterns of Discursive Moves for Selected Lessons

Coding within Studiocode enables both a visual timeline display of the patterns of teacher moves in response to student utterances, across a sequence and the construction of relative time spent on each type of move to enable a numerical comparison of the structure of the different teachers' responses. Figure 1 shows the Studiocode timeline for the KM episode. Each teacher utterance is coded for the category of discursive move it represents. An utterance is defined as having a single purpose, such that at times teachers might make sequential utterances coded as separate categories. The patterns show clearly the highly interactive nature of the classroom talk, including the extent of dominance of the student voice, and the range of types of discursive moves employed by the teachers. Figure 2 shows a restricted timeline showing only the broader discursive purposes, for one episode for each of the other teachers. In each case, it is apparent how these teachers move back and forth between the three broad functions of talk as they negotiate language and meaning.

For each episode, the total time spent on each of the discursive moves was recorded as a way of unpacking the nature of the practice. In the following tables, clip length refers to the amount of time (seconds) that was coded for each episode. Student Talk and Teacher Talk (%) refers to the amount of time coded where the students and teachers were talking, as a percentage of the clip length, respectively. Teacher Talk Time (seconds) was the total amount of time the teacher spent on conceptual talk, that is, within the coded categories of asking a New Question, Eliciting/Acknowledging, Clarifying or Extending and Elaborating. The percentage value for each category is a measure of the amount of time the teacher spent on talk within that category, as a percentage of Teacher Talk Time, e.g. 30 % Marking indicates the amount of time coded as Marking occupies 30 % of Teacher Talk Time.

Below, we describe the cases and examples of discourse from each to illustrate the discursive move patterns.

Bob's Lesson on Paper Drop

Bob is an experienced science specialist teacher in Melbourne, Australia. In an interview, he spoke about having a philosophy of teaching children so that they enjoy the process of learning about science and focuses on supporting the students to become science literate. Bob has a strong belief in student hands-on exploration and his classroom is rich in artefacts. In Table 2, three episodes from one of Bob's lessons are presented. This is a sequence in which Bob first explores students' ideas of push and pull from previous work (episode #1). Episode #2 is a further dialogic sequence in which he then poses the question of what affects the speed with which a sheet of paper drops, and gathers students' ideas

Table 1 A framework of teacher discursive moves

New Question	This involves asking a new question, which begins a new line of inquiry or discussion
ELICITING AND ACKNOWLEDGING	These are teacher moves that elicit and acknowledge student inputs and establish them as contributions that are valued in building understanding in the classroom. These moves include canvassing of further ideas and responses to input that vary from simple recognition of student contributions and to marking out contributions for special attention. They include positive evaluations and negative evaluations (for these teachers, the latter was uncommon). They are used when the teacher is encouraging and gathering responses to an initial question, to get ideas 'on the table' *The order of the sub categories reflects increasing shaping of students' responses*
1. Eliciting Further Responses/Re-stating Question	The teacher further elicits ideas by canvassing other students' input, or CLARIFYNG the nature of the question Asking the question again—'further ideas?' 'Anyone else?" Choosing another student with their hand up. 'Henry?' Asking the same question from a minimally different context, e.g. "Wood. Solid, liquid or gas? … Metal. Solid, liquid or gas?"
2. Acknowledging	Simply saying 'ok' without affirming or drawing particular attention. This could be a nod
3. Marking	The teacher marks out the student input in some way, as worthy of further consideration, for instance by repeating the student response or a key part of it without embellishment in order to draw attention to what was said, or underlining or otherwise highlighting it on the board
4. Affirming	Affirming interactions are those where the teacher offers a positive evaluative response to the student's response, e.g. 'exactly', 'you're right' or 'that's a good idea'. This could be a physical expression such as 'yes!' delivered with gusto, or a nod and smile. It could also be a repeating of the student answer, as with 'marking' above, but this time, with a turn of voice that makes it clear this is a valued or correct response
5. Evaluating Negatively	The teacher passes judgement on the contribution, which takes it out of contention as something to move forward with. 'No, that's not relevant', 'no', 'that's interesting but can't help us in this case'. It may be purely gestural, such as a head shake
CLARIFYING	These are a set of response moves aimed at CLARIFYING and sharpening the student input to achieve greater precision of meaning. These involve discursive devices that shift the language of student input to more scientific ways of talking about the phenomenon, from simply asking for students to be clearer about what they are saying, to re-voicing the input to subtly impose scientific language and perspectives *The order of the sub categories reflects increasing introduction of scientific language.*
6. Requesting Confirmation	Asking the student to confirm their intended meaning through repeating or slightly re-voicing the student's response, using different or more precise words, and asking for their agreement or not. 'So are you saying that … ?'
7. Requesting Clarification	Requesting a student to provide further information/interpretation concerning their response so it is clear what they meant
8. Re-framing Question	Asking the question in a different way, with the intent to clarify what is being asked. Asking the same question but in a slightly different context, to clarify what is being asked. 'That's not quite what I meant. Let me give you an instance. If …. '
9. Re-voicing	Re-casting the language of the student response to introduce scientific language, or a related new idea. Consolidating student responses by summarizing in more precise terms, imposing some order around scientific categories and

Table 1 (continued)

	conceptions. Occasionally these moves developed further into Elaborating moves where the science view was more formally presented
EXTENDING	These moves aim to shift students' ideas forward by challenging students to extend or re-think their ideas or use them in another context. These are discursive moves that invite students to embellish and go beyond current ideas, to justify their claims and to reason. This may involve a sequence of further EXTENDING questions that progressively open out students' thinking or it may involve requesting further opinion on students' input *The order of the sub categories reflects increasing challenge to students to refine, re-think and extend their ideas*
10. Requesting Elaboration	Requesting a student, based on their response, to talk further about their idea with the implication of EXTENDING and elaborating rather than simply CLARIFYING. 'That's interesting, can you talk some more about how this applies more generally' 'So if you say … can you be a bit more precise about … '
11. Canvassing Opinion	Asking for other students' opinion on the response. This move invites student-student interaction, and may involve students in claims, counter-claims and justifications. It may be simply 'who agrees with what …. said?'
12. Asking an EXTENDING Question	Asking a related question that introduces a new element to the question, that might highlight a conceptual link and ask for an extension of the idea. It may be part of a sequence of questions that take students by degrees deeper into understanding a phenomenon or a model, e.g. Bob establishes that two pieces of paper weight the same and then asks 'if I scrunch this one up do they still weigh the same?'
13. Challenging Directly	This is an action, question or statement designed to extend the thinking of students by challenging them to reconsider their response, e.g. Colin challenging the student notion of a solid being unbreakable by making a hole in a newspaper (solid). 'But if that's the case, wouldn't it imply that …?' 'Do you really think that … ', 'But doesn't that contradict what we just agreed about …?'
14. Challenging to Extend Ideas	This is an explicit challenge to students to use their idea in a new context or consider the implications of their idea in a new or problematic situation. e.g. discussing liquids "Sand can change its shape to fit a container. Is it therefore a liquid?" or "ok if you have that idea can you tell me what it would imply for *this other* situation"
Elaborating, presenting the scientific view	A relatively extended response that relates to but moves beyond what a student said and presents and elaborates on new science ideas. It may be a summing up of the whole discussion and EXTENDING to new explanatory ideas. It may be an illustrative, explanatory story that builds on a student response.

about this. Episode #3 follows group work in which students experimented in small groups with different modifications to sheets of paper and reported their findings. In this whole-class authoritative episode, he gathers these ideas together to establish that weight and air resistance are the main factors affecting the drop time.

Across all three episodes, Bob consistently uses Acknowledging and Marking teacher response moves to non-evaluatively respond to student ideas and to highlight the salience of the ideas that students are presenting. He rarely affirms (Affirming), and never negatively evaluates (Evaluating Negatively) student input. Episodes #1 and #2 are dialogic sequences with high levels of Eliciting/Acknowledging moves (primarily Acknowledging and Marking). Episodes #1 and #2 differ with a higher proportion of New Questions in the former, and a higher proportion of Clarifying teacher responses in the

Fig. 1 An episode of a Studiocode timeline for the KM school. It includes the usage of New Question and Student Talk and each of the subcategories of teacher moves. The codes from more Eliciting/Acknowledging codes are illustrated at the top of the timeline, moving towards Clarifying and Extending codes towards the bottom of the timeline

latter, largely about Re-framing Questions which are used to focus attention on the need to control conditions for comparing paper drop times. See transcript below from episode #2.

T: How can I make one hit the ground before the other?	New Question
T: How can I make one of these pieces of paper … sorry how can *you* [selects student] make one of these pieces of paper hit the ground first?	Re-stating Question
S: By lifting one higher than the other one.	
T: Like this … [raises horizontal papers, so that one is higher than the other]. Hadn't thought of that possibility but [drops papers] yes that is true, that works.	Acknowledging
T: If I keep them at the same height, how can I get one to hit the ground before the other?	Re-framing Question
S: Let go of one first.	
T: Yes I could let go of one first.	Marking
T: I'm keeping them at the same height, I'm letting go of them at the same time, how can I get one to hit the ground first?	Re-framing Question
S: By scrunching one up.	
T: Scrunching.	Marking
T: What would happen if I scrunch it up?	Requesting Elaboration
S: [Student looks thoughtful, but does not offer a reply]	
T: [Teacher scrunches up one piece of paper. He holds the two pieces of paper (one scrunched) out horizontally and drops them at the same time. The scrunched up piece of paper hits the ground first.] Why the scrunched up one?	Asking an Extending Question

In the authoritative episode (#3), he uses a combination of extending questions (Asking an Extending Question) ('did it drop because it was thicker or because … ?', 'when I scrunch it up, do I change its weight?'), requests for elaboration (Requesting Elaboration) (To a student saying 'The scrunched up one has more force so it goes down first', he asks, ' … where's the force coming from?') and for confirmation (Requesting Confirmation) (the student offers 'scrunched up' and Bob responds '…oh I see, if you scrunch something up it has more force?', and Re-voicing (in discussing whether scrunching paper changes its weight, a student claims that scrunched paper does not catch the air, and Bob summarizes 'It doesn't catch the air but it still weighs the same') to move his students towards a scientific understanding.

Colin's Lessons on Matter

Colin is a specialist science teacher in Victoria, Australia. In an interview, he talked about having a strong science literacy focus and a belief in challenging his students'

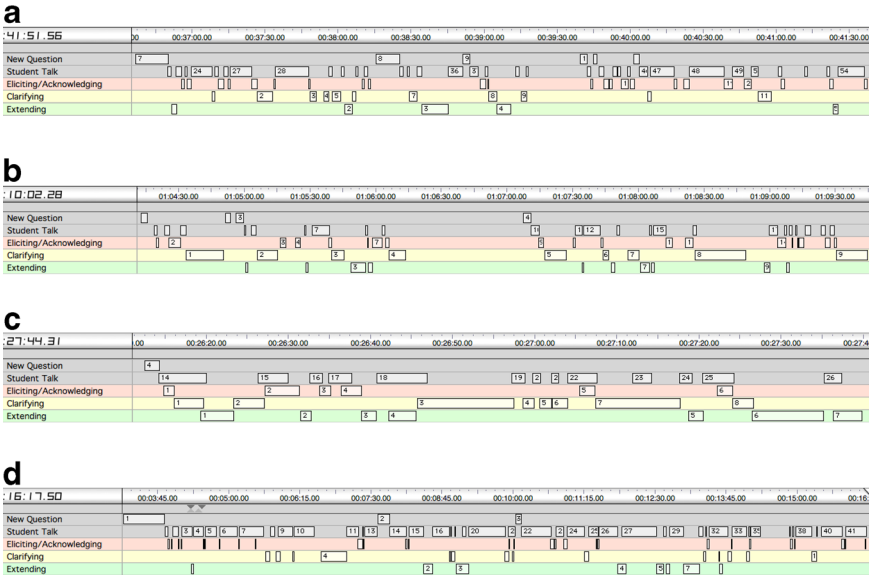

Fig. 2 Episodes of timelines for **a** Bob **b** Colin, **c** Mrs. Hong and **d** KM Teachers. These illustrate the pattern of New Question and Student Talk, and the usage of teacher moves from each of the major categories—Eliciting/Acknowledging, Clarifying and Extending

ideas to encourage refinement in their language. In Table 3, three episodes from Colin's sequence are presented. Episode #1 is a dialogic sequence where Colin explores students' ideas of what characterizes a solid without imposing the scientific view. In the authoritative episode #2, he works with students' ideas about solids after a series of exploratory activities. In Episode #3, he establishes a scientific perspective through working with his students' ideas about the viscosity and density of liquids following activities exploring a series of liquids. His approach in these authoritative sequences is to gather students' ideas together and Re-voice their responses using a more scientific vocabulary. This move from dialogic to authoritative is consistent with Bob's sequencing, and descriptions of inquiry approaches as noted above (Scott, 1998).

In the dialogic sequence (Episode #1), Colin uses a high proportion of Eliciting/Acknowledging teacher responses, frequently Re-stating Questions and Marking, working to elicit a large number of responses from his students and drawing attention to particular responses. A characteristic of his discursive practice is his consistent finding of opportunities to challenge students' thinking. He does this by directly challenging (Challenging Directly) students about their ideas and challenging them to extend their ideas (Challenging to Extend Ideas) by putting their definitions into new contexts in an effort to promote reasoning. In the more authoritative sequences (episodes #2 and #3) Colin uses Clarifying teacher responses, Re-voicing the language of his students, moving them towards a more scientific use of language. Wherever possible, he continues to extend their thinking by asking for more information (Requesting Elaboration), challenging them (Challenging Directly) and asking extending questions (Asking an Extending Question).

Colin frequently uses Eliciting/Acknowledging moves, coupled with challenges to their reasoning. This is especially true of dialogic sequences, as demonstrated in episode #1 of Table 3 and the episode below where he uses Extending teacher

Table 2 Bob's discursive moves in three episodes

	Episode #1	Episode #2	Episode #3
	Dialogic	Dialogic	Authoritative
Clip length (s)	70	194	314
Student Talk (%)	56	32	37
Teacher Talk (%)	37	36	40
Teacher Talk (TTT) (s)	26	69	126
New Question (%)	38	10	26
Acknowledging (%)	46	42	31
Re-stating Question (%)	4	12	6
Acknowledging (%)	23	6	6
Marking (%)	19	11	15
Affirming (%)			4
Evaluating Negatively (%)			
CLARIFYING (%)	15	36	24
Requesting Confirmation (%)		3	11
Requesting Clarification (%)	8		
Re-framing Question (%)	8	33	6
Re-voicing (%)			7
EXTENDING (%)	0	12	19
Requesting Elaboration (%)		9	8
Canvassing Opinion (%)			
Asking an EXTENDING Question (%)		3	9
Challenging Directly (%)			2
Challenging to Extend Ideas (%)			

responses, seizing on the students' new ideas and challenging their new definitions of the characteristics of a solid.

S1: It's like really really strong and like you can hardly break it, unless you have something like …	
T: So does that mean what S1 says? It's difficult to break? Yeah?	Requesting Elaboration
T: S2?	Re-stating Question
S2: Well if you have like a container with something solid in it, and then you had a crack in that container, it wouldn't fall through the crack.	
T: So. It wont … it won't change its shape to fit through a crack. Is that what you're saying?	Requesting Confirmation
T: So does that say the same thing as this [indicating to white board] can't change its shape? Cos if something's going to go flowing through a crack, a tiny little crack in the bottom of a glass, it needs to change shape doesn't it?	Challenging to Extend Ideas
S: It needs to go thin.	
T: Yeah, which we know that liquids can do can't they?	Re-voicing

Table 3 Colin's discursive moves in three episodes

	Episode #1	Episode #2	Episode #3
	Dialogic	Authoritative	Authoritative
Clip length (s)	346	425	509
Student Talk (%)	32	13	30
Teacher Talk (%)	38	39	56
Teacher Talk (TTT) (s)	132	164	286
New Question (% of TTT)	15	7	11
Acknowledging (%)	43	23	26
Re-stating Question (%)	14	10	3
Acknowledging (%)	8	2	18
Marking (%)	20	2	0
Affirming (%)		7	0
Evaluating Negatively (%)		1	5
CLARIFYING (%)	15	57	51
Requesting Confirmation (%)	10		
Requesting Clarification (%)	3		5
Re-framing Question (%)			1
Re-voicing (%)	2	57	45
EXTENDING (%)	27	13	12
Requesting Elaboration (%)	2	4	8
Canvassing Opinion (%)			
Asking an EXTENDING Question (%)		9	1
Challenging Directly (%)	2		3
Challenging to Extend Ideas (%)	22		

Mrs. Hong's Lesson on Moon Phases

Mrs. Hong is a specialist science teacher in Taipei, Taiwan. In an interview, she emphasised the use of a variety of teaching strategies and contexts to achieve conceptual learning goals and equip students for future learning. The teaching context in Taiwan includes a highly structured curriculum supported by text and multimedia resources. In Table 4, three of Mrs. Hong's episodes are presented. In these episodes, she is continually and strongly shaping the discourse towards scientific language and ideas, characteristic of authoritative talk. She continually monitors students' thinking, and students are given the opportunity to express opinions, but in a constrained context. All three episodes are characterized by a high percentage of Teacher Talk and the lessons themselves were strongly teacher-guided.

The three episodes are all from one lesson, with episode #1 being towards the beginning of the lesson, episode #2 towards the middle and episode #3 towards the end of the same lesson. These episodes demonstrate changes throughout the lesson as Mrs. Hong uses Acknowledging and Clarifying teacher responses in episode #1. She elicits a

Table 4 Mrs. Hong's discursive moves in three episodes

	Episode #1	Episode #2	Episode #3
	–	–	–
Clip length (s)	61	44	90
Student Talk (%)	13	32	41
Teacher Talk (%)	87	84	82
Teacher Talk (TTT) (s)	53	37	74
New Question (% of TTT)	21	32	3
Acknowledging (%)	43	0	18
Re-stating Question (%)	19		1
Acknowledging (%)	2		
Marking (%)	19		3
Affirming (%)	4		14
Evaluating Negatively (%)			
CLARIFYING (%)	32	68	49
Requesting Confirmation (%)	11	35	
Requesting Clarification (%)	4	8	3
Re-framing Question (%)	9	3	24
Re-voicing (%)	8	22	22
EXTENDING (%)	4	0	31
Requesting Elaboration (%)	4		
Canvassing Opinion (%)			
Asking an EXTENDING Question (%)			23
Challenging Directly (%)			4
Challenging to Extend Ideas (%)			4

higher number of student responses by re-stating her questions (Re-stating Questions) and marking student responses (Marking). In episode #2, she uses more Clarifying teacher responses, ensuring that everyone is understanding what they are doing (Requesting Confirmation) and then re-voicing their responses (Re-voicing), to move the students towards a more scientific use of language. In episode #3, she is moving towards the end of the lesson, using more Clarifying and Extending responses. She gets to get them to look at different concepts she is working with (Re-framing Questions) and she continues to use Re-voicing. She also moves them towards the final ideas of the lesson by asking extending questions (Asking an Extending Question), and challenges their ideas (Challenging Directly and Challenging to Extend Ideas).

T : Now I want you to tell me, when the moon moved from position 1 to 2 … when it's at position 2, which part of the moon is lit up?	New Question
S : Half.	
T : Which half? Is it left half or right half?	Requesting Clarification
S: [Students responding]	

T : When you look at the moon, half of it is lit up, right?	Requesting Confirmation
S: [Students responding]	
T : Do you agree? [Asking every group] Group 4 and 5 agree. So does group 1 … group 2 .... group 3 … Are you sure?	Requesting Confirmation
S: [Students responding]	
T : Good! Now all the aliens, please tell me, the moon you see, which side is bright?	New Question
S: [Students giving different answers]	
T : Hm? It's still half bright, isnt' it. But to the earthmen, they can only see the right part is bright.	Re-voicing

In the episode above, Mrs. Hong is consistently driving the class, but ensuring that students are keeping up and observing subtle aspects of the phenomena in question by asking Clarifying questions that require short and specific responses ('Do you agree?') ('When you look at the moon, half of it is lit up, right?').

KM School

The German case involves a pair of teachers who have been trained to teach using a methodology focused on student dialogue, based on the principle that students can discover key principles by means of systematic verbalization with the help of the teacher. The teachers encourage students to clarify and elaborate on their ideas, and to consider each other's ideas. In Table 5, analysis of an extended episode for the German case is presented. This episode is towards the end of a sequence of lessons on levers. In previous lessons, they worked through various episodes of levers, including levers that could lift other students and examples of levers used in transportation and construction.

This episode is characterized by high levels of Student Talk, Clarifying and Extending teacher responses. The teachers are consistently asking students to clarify their ideas (Requesting Clarification), talk more about them (Requesting Elaboration) and getting them to think of their ideas from other perspectives (Challenging to Extend Ideas). At the same time, the teachers are using Re-voicing to move their students towards a more scientific use of language. In the following episode, the students and teachers are talking about an investigation where students explored where to place wooden bricks across poles to best support a toy gondola hanging off the side of a desk.

T1: I would be interested to know whether the children who placed things here in the back have a reason why they placed things in the back? S1?	New Question
S1: Well, first because it looks nice. And second, ehm, why is it built in the back?, well if it's in the front one only needs to touch it slightly with the knee or arm and then it immediately falls down.	
T1: uhum.	Acknowledging
T1: S2??	Re-stating Question
S2: Also because if one places it more to the back, well, if one builds it more to the front then the poles in the back will lift, so the danger that it falls is greater.	
T1: Describe more precisely what you noticed while constructing. Say this again but in more words.	Requesting Elaboration

S2: Well if one places the bricks in the back then the poles will not rise in the back. And if one places them in the front, then they will rise in the back and then..	
T1: This happened to you?	Requesting Confirmation
S2: Yes.	
T1: When you had this further in front the beams tilted?	Requesting Confirmation
S2: Yes.	
T1: Ok. I remember S3 also had such a situation where you [pointing at S3] the pole almost came into your face, right?	Requesting Elaboration
S3: I got it in my face.	
T1: You did, really. Can you remember how the stones were placed then?	Requesting Elaboration

As can be observed in the episode above, the KM teachers are consistently asking Clarifying questions that highlight experiences that the students have had ('This happened to you?') and asking them to elaborate on those experiences ('Can you remember how the stones were placed?'). They ask their students to elaborate in a quite specific manner ('Describe more precisely … but in more words').

Table 5 KM teachers' discursive moves

	Dialogic-Authoritative
Clip length (s)	786
Student Talk (%)	65
Teacher Talk (%)	46
Teacher Talk (TTT) (s)	234
New Question (% of TTT)	26
Acknowledging (%)	17
Re-stating Question (%)	5
Acknowledging (%)	12
Marking (%)	
Affirming (%)	
Evaluating Negatively (%)	
CLARIFYING (%)	29
Requesting Confirmation (%)	
Requesting Clarification (%)	13
Re-framing Question (%)	
Re-voicing (%)	16
EXTENDING (%)	27
Requesting Elaboration (%)	20
Canvassing Opinion (%)	
Asking an EXTENDING Question (%)	
Challenging Directly (%)	
Challenging to Extend Ideas (%)	7

Differences Between the Four Cases

The discursive structure for any particular teacher varies across episodes, so that averaging indicators of practice across episodes is potentially misleading if taken to represent some essentialised feature of practice. Nevertheless, such an analysis can clarify differences in the teachers' practice. Table 6 shows the overall percentage of teacher talk in the major functional categories, for each teacher across the whole-class parts of the lesson.

We see certain features highlighted that provide insight into characteristic modes of discursive practice for the teachers. First, Bob has the highest incidence of Eliciting/Acknowledging moves, reflecting the emphasis he puts on exploration and probing of student ideas, and correspondingly less emphasis on formal, declarative scientific knowledge, at least in this instance. Colin has in common with Mrs. Hong a strong emphasis on Clarifying moves. However, for him, Re-voicing moves dominate, in which he imposes, sometimes gently but often very explicitly, scientific language on students' contributions. For Mrs. Hong, the Clarifying moves are shared between Re-voicing and Requesting Confirmation or Requesting Clarification, as she monitors students' responses to the ideas she introduces. Interestingly, the bulk of Colin's Extending moves occur within the dialogic section, where he challenges students to maintain and justify ideas they put forward. For both Colin and Mrs. Hong, the science ideas are introduced by the teacher, more so than for Bob and the KM teachers.

The key distinction to be made in the case of the KM teachers is the high level of extending moves, where students are asked to elaborate on and extend their ideas. This, combined with a very high percentage of student talk, shows how students' ideas are a prime driving force behind conceptual discussions. The other notable characteristic is the length of individual student responses. These often involved elaborated reasoning moves including analogies, speculation and justification, as evidenced by the short sequence shown above.

Discussion

The analysis of patterns of discursive moves made by these teachers representing expertise in disparate settings has identified a discursive richness that goes well beyond the classic simple IRE sequence described so often in the literature, in which student responses are narrowly channelled and there is little room given for elaboration of

Table 6 Each teacher's percentage of talk in the major discursive move categories

	Bob	Colin	Mrs Hong	KM class
Student Talk (Student Talk Time / Total Student + Teacher Talk Time) (%)	51	35	25	69
Eliciting/Acknowledging (%)	40	31	20	17
CLARIFYING (%)	25	41	50	30
EXTENDING (%)	10	17	12	27

student ideas. These teachers rarely evaluated in any judgmental sense, but prompted and responded to student input in a variety of ways. The analysis in effect offers a detailed unpacking of teacher prompts (Mortimer & Scott, 2003; Scott, 1998). These moves serve to move thinking forward through acknowledging, shaping and extending student language and ideas, rather than imposing science ideas in a manner unconnected with student experience and thinking. The moves have been identified as falling within three broad categories of purpose—Eliciting/Acknowledging, Clarifying, and Extending—which are all well represented in these expert teachers' practice, and provide shape to the conceptual intent of lessons. The overwhelming impression in each case is one of strategically planned and executed practice in which the shaping of knowledge is shared between the students and teacher. This practice moves well beyond simple IRE patterns in which teachers' knowledge is dominant and student ideas are given very little opportunity to emerge. The framework is potentially powerful for clarifying ways in which teachers can engage with and develop students' ideas in strategic ways.

These teaching episodes display characteristics broadly associated with inquiry teaching, in their exploration of student ideas and gathering evidence together to develop and support scientific perspectives (Anderson, 2002). They do this, however, in different ways using different structures. Bob's lesson on paper dropping through air exhibits the classic distinction between dialogic and authoritative discourse segments (Mortimer & Scott, 2003). Episode #2 conforms to a dialogic discourse mode, as Bob works to get student ideas on the table, with a high incidence of Re-stating the question to clarify what is being asked, Acknowledging and Marking responses. The students experiment and generate explanatory ideas, and in episode #3, Bob moves them very deliberately to identify air resistance and weight as the two forces that determine the drop time. In this sequence, we see a shift in emphasis towards Clarifying and Extending moves, with Requests for Confirmation, Re-framing and Extending questions and Re-voicing as his tools for guiding student ideas towards resolution.

Similarly, Colin's episode #1 was identified as dialogic, and #2, which was from the same lesson, authoritative in character. Again, from #1 to #2, we see a shift from an emphasis on Eliciting/Acknowledging moves towards Clarifying and Extending moves, with the use of Re-voicing particularly marked in the authoritative episodes (#2 and #3). Occasionally, these extended into expository Elaborating discourse that laid out the scientific view beyond the student talk. Colin front-loaded definitions of solid-liquid-gas and had students explore their meaning with a variety of materials. Interestingly, challenging students to extend their thinking is a strong part of his approach to sharpening the form of students' contributions.

Mrs. Hong's approach was to put ideas on the table and then work with students' responses to these as she monitored and extended their thinking. We would therefore characterize her approach as authoritative throughout, with consistent shaping across the lesson. Nevertheless, there was a structure to the lesson on earth-moon models, moving from introducing the 3D and 2D models and exploring and refining students' perspectives on these, gathering them together around an abstracted model at the end. As with the other teachers, there is a shift from Eliciting/Acknowledging towards Clarifying and finally Extending moves. In this case, Re-voicing and asking sequences of Extending questions are characteristic of her discursive practice.

The KM classroom teachers' practice was an interesting case, at each point having both dialogic and authoritative features. From the Studiocode timeline, we see a constant movement between the three discursive functions, with Extending moves clustering half and three quarters through the episode. In this lesson, ideas about the lever arm models were canvassed and moved forward by a subtle guiding process using Requests for Clarification and Elaboration and Re-voicing.

Distinct from the quantitative patterns of discursive moves represented by Tables 2, 3 and 4, the analyses demonstrate the very deliberate way these are designed to build student understanding. Bob structures his sequence on dropping of paper and air resistance to canvass student conceptions and selectively use them as elements to build towards ideas of weight and air resistance as the key factors in the fall. Colin progressively canvasses and challenges students' ideas around the characteristics of solids, liquids and gases to build an understanding across a variety of materials. Mrs. Hong structures her role-play of the earth-moon system very deliberately to emphasise the link between earthbound and space perspectives. The KM teachers structure their activities and nudge the conversation towards recognition of the notion of lever arms in determining forces. Each of these teachers seems to have a very clear perspective on where the classroom conversation is heading, that informs the way they orchestrate their questions and responses to student input. The teachers' art consists, therefore, not simply in the ability to deploy this range of discursive moves, but also in the clarity of purpose to which these are put. This shaping of ideas across the time scale of a lesson can be linked to Lemke's (1990) thematic patterns of scientific meaning.

Notwithstanding that expertise involves in the ability to deploy a range of discursive moves to pursue a coherent conceptual agenda, the balance and patterns of use of these were idiosyncratic, related to teacher belief and arguably to context and tradition in these systems. Thus, Colin's belief in challenging students as part of a literacy agenda shows clearly in the number of challenge moves he makes. Mrs. Hong's belief in strong conceptual preparation of students and her belief that providing a strong conceptual framework increases the efficiency of learning is reflected in the lower incidence of student talk, and in the strong framing of the discourse through Re-framing and Extending questions, and Re-voicing. The KM teachers' commitment to giving students voice is evident in the high level of Extending moves they make, particularly requests for students to elaborate on their ideas. We can see from the analysis that as one moves through a lesson structure from dialogic to authoritative or from introduction of models to their explanatory use, the patterns of discursive moves shift towards the higher order purposes of Clarifying and Extending. The Extending moves, in particular, involve students in responding to challenges, consistent with argumentation practices in science and science education (Osborne, 2010) around claim making, rebuttal and justification.

From the point of view of usefulness of the analysis and framework for teacher learning, we see it as having four important features.

1. The identification of a range of specific expert teacher discursive moves. These moves overlap with previous schemes proposed by a range of researchers (Alexander, 2006; Barnes & Todd, 1977; Lemke, 1990; Mercer, 2004; Mortimer & Scott, 2003; Scott, 1998) but are more comprehensive and more specific in their descriptions, such that they establish a language through which teachers and

teacher education students can examine and develop their own practice. Most moves are well represented across most of the cases despite the different pedagogical stances.

2. The identification of three broad discursive functions central to working with student's ideas to establish scientific perspectives and language. This provides a structure through which teachers can understand how Eliciting and Acknowledging, Clarifying and Extending student ideas are central categories of moves that support high-level thinking and reasoning in whole class discussions in science. These go well beyond the simple IRE discursive pattern, and the balance of utterances across the levels provides an indicator of the extent to which teachers are supporting students at this level.
3. The identification of patterns of use of these discursive moves in short sequences and more broadly across a lesson. These teachers move continually between clusters of Eliciting/Acknowledging moves and Clarifying, Extending moves, as they work with students' ideas and establish scientific language. Across a lesson, we consistently see the move towards Clarifying and Extending moves as the lesson proceeds. These teachers seemed to have in each case clearly articulated the structure of key ideas to be pursued, allowing them to be deliberative in responding to students' input.
4. The applicability of the framework across a range of different pedagogical contexts and teacher beliefs. These teachers used a wide variety of moves, including the KM teachers' highly student-centred approach, and the more teacher-centred approach of Mrs. Hong. The framework does not promote a particular type of strategy or approach but represents the more fundamental principle that students should be supported to explore and articulate their ideas as a key element of establishing science knowledge. The degree of teacher framing of ideas affects the balance of discursive moves, but not the overall structural or temporal patterns of use.
5. The different ways in which the dialogic-authoritative distinction plays out, with only the Australian teachers having distinct, separated episodes that can be characterized as one or the other. The KM case shows the possibility of closely interweaving of dialogic and authoritative discourse in whole class discussion, building on student experimentation and prior ideas. The Taiwanese case shows how authoritative discourse can still allow room for student ideas to be voiced, albeit within much tighter conceptual framing.

We are not presenting this framework as a set of codes that can be universally applied to make objective judgments about teachers' practice based on the numerical patterns of their discursive moves. It is clear from Tables 2, 3 and 4 that the particular part of the lesson, and the type of lesson, will affect the patterns of language. Further, the distinctions between some of the categories were difficult to make objectively given they rely on subtle judgments of conceptual intent and the context of the statement. The categories, however, are distinct in their intended function. We argue, rather, that the framework can serve as a useful tool to make apparent teachers' discursive moves in promoting student understanding and reasoning, and to help teachers' articulate powerful ways of doing this. In analysing these lessons, we became much more aware of teachers' orchestration of the patterns of meaning making.

Conclusion

In this analysis of the discursive moves of five expert teachers of science, we have constructed a framework that is more specific and structured than those previously attempted. The framework identifies three broad discursive functions through which teachers undertake the complex task of working with students' ideas to establish science understandings. This teaching programme lies at the heart of any approach that attempts to take seriously the need to engage with and monitor student understanding.

The teachers in this analysis all had in common that they operated at all three functional levels, albeit with different balances in discursive moves dependent on beliefs and context. The patterns of moves progressed over a lesson towards Extending moves that encourage student reasoning and deeper thinking about science. The framework thus was able to make sense of these expert teachers' practice despite the very different traditions within which they operate.

We argue that the framework, based on micro-ethnographic analysis of video of expert teachers' practice, can offer a powerful means by which teachers and teacher education students can examine their own practice and develop approaches to teaching and learning science more aligned with expert practice. An important part of the requirement for such learning will inevitably be the need for clarity about the conceptual intent of any lesson, since it was clear these expert teachers' selection of discursive moves was based in a clear and strategic view of both learning goals and the conceptual difficulties attendant on these.

We have already begun working with student teachers using the framework, with encouraging results. We will also work with the framework to analyse further teachers' practice in the EQUALPRIME countries, to explore in more detail the effects of local cultural context of schooling and teaching on patterns of discourse.

References

Alexander, R. (2006). *Towards dialogic teaching: Rethinking classroom talk* (3rd ed.). Cambridge, UK: Dialogos.

Anderson, R. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education, 13*(1), 1–12.

Bakhtin, M.M. (1981). *The dialogic imagination: Four essays* (C. Emerso & M. Holquist., Trans.). Caryl Emerson & Michael Holquist. Austin,TX: University of Texas Press.

Barnes, D. & Todd, F. (1977). *Communicating and learning in small groups*. London, England: Routledge & Kegan Paul.

Driver, R., Asoko, H., Leach, J., Mortimer, E. & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5–12.

Edwards, D. & Mercer, N. (1987). *Common knowledge: The development of understanding in the classroom*. London, England: Methuen.

Johnstone, B. (2002). *Discourse analysis*. Oxford, England: Blackwell.

Landis, R. J. & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*(1), 154–174.

Lemke, J. L. (1990). *Talking science: Language, learning and values*. Norwood, NJ: Ablex Publishing.

Mercer, N. (2004). Sociocultural discourse analysis: Analysing classroom talk as a social mode of thinking. *Journal of Applied Linguistics, 1*(2), 137–168.

Mercer, N., Dawes, L., Wegerif, R. & Sams, C. (2004). Reasoning as a scientist: Ways of helping children to use language to learn science. *British Educational Research Journal, 30*(3), 359.

Mortimer, E. F. & Scott, P. H. (2003). *Meaning making in secondary science classrooms*. Maidenhead, UK: Open University Press.

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science, 328*, 463–466.

Scott, P. (1998). Teacher talk and meaning making in science classrooms: A Vygotskian analysis and review. *Studies In Science Education, 32*, 45–80.

Sinclair, J. & Coulthard, M. (1975). *Towards an analysis of discourse: The English used by teachers and pupils*. Oxford, England: Oxford University Press.

Vygotsky, L. (1981). *Thought and language* (Rev. ed). A. Kozulin(Ed.). Cambridge, MA: MIT Press.