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Dialogic interactions in the cooperative classroom

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ABSTRACT

Attention in recent years has turned to the key role talk plays in mediating students' learning when they work cooperatively together. There is no doubt that talk, albeit by the teacher or peers, has the capacity to stimulate and extend students' thinking and advance their learning. Teachers do this when they encourage students to engage in reciprocal dialogues where they exchange information, explore issues, interrogate ideas, and tackle problems in a cooperative environment that is supportive of these discussions. In turn, students learn to listen to what others have to say, consider alternative perspectives, and engage critically and constructively with each other's ideas by learning how to reason and justify their assertions as they cooperate together. This study involved three Year 7 teachers and 17 groups of students (3–5 students per group) from their classes. The teachers had agreed to teach two units of cooperative, inquiry-based science across two school terms. All three teachers had been trained to use a dialogic approach to teaching designed to challenge children's thinking and learning. This paper presents examples of both teachers' and students' dialogic interactions and discusses the complementarity of these discourses even though the teachers used slightly different dialogic approaches in interacting with their students.

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1. Introduction: teacher prompting and mediating

Teachers play a key role in teaching students to ask and answer questions if students, in turn, are to learn how to engage in reasoned argumentation where they are required to investigate topics, consider alternative propositions, explain their own thinking, and problem-solve together to reach consensus on an agreed topic (Gillies, 2013; Gillies, Nichols, Burgh, & Haynes, 2012). While it is well recognised that students have a natural curiosity to learn, research also indicates that they rarely ask and pursue questions about their own learning unless they are explicitly taught to do so (Meloth & Deering, 1999). Students do not engage in explanatory behaviour, ask though-provoking questions, or draw upon previous knowledge and experiences without some external guidance (King, 2002). Similarly, Chinn, O'Donnell, and Jinks (2000) noted that students only engage in high-quality discourse when they are required to provide reasons and justifications for their conclusions. Galton, Hargraves, Comber, and Pell (1999) attributed students' poor quality discourse to teachers who rarely asked cognitively challenging questions where students were required to link information and understandings about issues and to justify their responses. In fact, the general pattern of teachers' discourse tended to fall into two categories. The first involved teachers asking traditional information–response–feedback (IRF) questions where students

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were required to provide pre-determined responses while the second involved teachers making statements that required no further elaboration. This pattern of discourse was so entrenched Galton et al. observed that over the 20-year period that was the subject of the investigation (1976–1996), teachers' propensity to provide facts or ideas and give directions had increased markedly so that it now represented over 80% of teachers' total talk in classrooms.

Sadly, recent research by Howe and Abedin (2013) on classroom dialogue across four decades indicates little has changed with classroom dialogue continuing to revolve around teacher–student IRF interactions. The ubiquity of this type of discourse may, in part, be due to teachers' tendency to see teaching as a transmission process where students are instructed in basic information and *talked at* rather than *talked with* (Alexander, 2008a; Galton, Hargreaves, Comber, & Pell, 1999). It may also be due to the organisational structure of the classroom where students rarely work in groups and if they do, they are seldom structured to facilitate rich dialogic exchanges of ideas and opinions (Howe & Abedin, 2013).

Alexander (2008a) argues that the consequences of this type of dialogic exchange where talk is essentially one-sided and cognitively unchallenging are threefold: firstly, children may not learn as effectively as supposed; secondly, children's potential to engage in dialogic interactions that challenge current perspectives or demonstrate their explanatory capacities may be inhibited or less developed; and finally, teachers may be ill-informed about students' understandings, and as a consequence ''lose the diagnostic element that is essential if their teaching is to be other than hit-or-miss'' (p. 93).

Dialogic interactions between teachers and students are critically important for student learning. Mercer and Littleton (2007) proposed that such interaction can be promoted by the different types of questions teachers pose that have a range of communicative functions. For example, questions can be used to: (a) test children's factual knowledge; (b) encourage students to make explicit their thoughts, reasons and understandings; (c) model ways of using language that children can appropriate for themselves; and (d) provide opportunities for students to engage in sustained interactions that enable them to articulate their understandings and clarify any misconceptions. While the types of questions asked are dependent on the context in which learning occurs (e.g., whole class teaching or collaborative group work), Alexander (2008a) argues that teachers need to have a pedagogical repertoire to accommodate these different approaches to teaching. Included in this repertoire are strategies for promoting *teaching talk* and *learning talk* with teaching talk involving teachers in discussions and dialogic exchanges with their students so their students, in turn, learn to explain, ask different types of questions, explore and evaluate ideas, argue, reason and justify, and negotiate outcomes. Alexander referred to this type of teaching as dialogic teaching.

1.1. Dialogic teaching

Dialogic teaching is predicated on five principles designed to ensure that interaction is dialogic as opposed to transmissive which is commonly found in many classroom today. These principles of dialogic teaching require teaching to be: (a) collective in that teachers and students work together to address learning tasks; (b) reciprocal so that teachers and students attend to each other, share ideas, and consider alternative perspectives; (c) supportive where students assist each other's learning; (d) cumulative in that teachers and students build on each other's ideas to construct coherent investigations; and (e) purposeful with teachers ensuring that discussions are designed to achieve specific educational goals (Alexander, 2008b).

In the dialogic classroom, Alexander (2008b) reports, teachers use more high-level questions that probe students' thinking and encourage them to analyse and speculate on ideas, student-teacher exchanges are longer with students building on the ideas of others or challenging different propositions with evidence, teachers provide students with more thinking time to respond to questions, and teachers questions are more focused and genuinely open with less emphasis on questions that cue for specific responses. In turn, Alexander notes, students attend more to what other students have to say and talk more purposefully towards solving problem issues, there is more student to student interaction, and there is greater participation of less-able children in class discussions. Furthermore, this emphasis on talk has led to improvements in reading and writing outcomes for all students, including the less-able.

Others who have examined the role of different types of talk in classrooms include Scott, Mortimer, and Aguiar (2006) who investigated the different types of talk demonstrated in science classrooms. Building on the research on dialogic teaching proposed by Alexander (2008a) and the role of inquiry learning in science (Osborne, 2002) where emphasis is attached to having students work collaboratively on open-ended tasks so talk is critically important to solving the problem at hand, Scott et al. have developed a communicative framework that helps to illustrate the types of talk that occurs in science classroom between teachers and students which they plotted on a dialogic-authoritative dimension. In the former, the teacher attempts to involve students in discussing their ideas, considering different perspectives, and exploring options before arriving at a solution to the problem being discussed. In contrast, authoritative discourse involves the teacher focusing students' attention on the problem as they are led through a question and answer regime, often very similar to an IRF interaction, with the intention of consolidating students' understanding of the problem.

Given the different types of discourse evident in classrooms and, in particular, science classrooms, how can teachers guide meaning-making interactions among students so students, in turn, learn how to engage in the task at hand? Engle and Conant (2002) propose that students are more likely to engage in productive classroom discourse when they are encouraged to accept intellectual challenges, they are empowered to address such challenges, they understand they are accountable to others and to disciplinary norms, and they are provided with the resources needed. Resnick, Michaels, and O'Connor (2010) also recognised the importance of classroom talk, arguing that "discussion-based classroom practices that combine rigorous tasks with carefully orchestrated, teacher-led discussion can support the growth of both disciplinary knowledge and the capacity to engage in reasoned discussion" (p. 173). In science, for example, students would make a claim and then present the facts that support the claim while others would have opportunities to rebut the presented evidence with alternative explanations. Resnick et al. referred to this type of classroom dialogue as *accountable talk* because it involves students learning to be accountable to the learning community in which they work and accountable to standards of reasoning and knowledge within the discipline.

Others who have investigated the powerful effects of classroom talk on students' learning and problem-solving and reasoning include Mercer, Wegerif, and Dawes (1999) and Wegerif, Mercer, and Dawes (1999) who used a dialogic tool that they called Exploratory Talk to help children to reason together as they work on collaborative problem-solving activities.

1.1.1. Exploratory talk

In exploratory talk, students are taught how to engage critically and constructively with each other's ideas where they can challenge and rebut different propositions while presenting alternative hypotheses (Wegerif, Mercer, & Dawes, 1999). In order to be able to participate effectively in these types of dialogic exchanges, students are taught specific ground rules for the way they will interact, including accountability for reasoning and knowledge which will be visible in their talk. These rules include: sharing all relevant information; seeking to reach consensus; accepting group responsibility for decisions made; providing reasons; accepting challenges and discussing alternative propositions before making a decision; and encouraging all group members to speak.

Mercer, Wegerif, and Dawes (1999) found that when students engage in joint reasoning activities using exploratory talk, it not only helps them to develop better ways of using language as a tool for reasoning together but the ability to reason improved students' scores on the Raven's Progressive matrices, a standardised test of individual reasoning and problem-solving. Rojas-Drummond, Perez, Velez, Gomez, and Mendoza (2003) also found substantial improvements in group and individual problem-solving among students who used exploratory talk to make their reasoning visible to their peers in comparison to control students. Similarly, Rojas-Drummond and Zapata (2004) observed that students who had been trained to use exploratory talk as a tool for reasoning and problem-solving produced significantly more and better arguments and provided more links and supports to sustain their opinions than untrained peers.

1.1.2. Philosophy for children

Another dialogic tool that is used to help students reason and problem-solve is Philosophy for Children (P4C). In P4C, children are taught how to work constructively together to develop an inquiring outlook towards problems and issues, engage in imaginative and adventurous thinking, examine issues and ideas critically, and demonstrate a capacity for exercising independent judgement (Lipman, 1988a, 1988b). In order to be able to conduct a good inquiry, students need to learn how to pose questions that will help them to explore and analyse issues in-depth; questions that help them probe alternative perspectives, explore causal connections and relationships, and pose hypothetical problems, through to those that challenge them to be more self-reflective and self-monitoring. It is through the dialogic exchanges that occur that children learn to engage in reasoned argumentation that helps them to clarify their understandings and facilitate their thinking (Reznitsakaya, Anderson, & Kou, 2007).

Others who have found that dialogical interactions promote the development of critical and creative problem-solving skills and enhanced cognitive ability in students include Trickey and Topping (2006) and Topping and Trickey (2014). Using P4C, the authors investigated the effects of this approach to dialoguing on students' academic, social, and cognitive abilities with the Trickey and Topping (2006) finding significant positive socio-emotional effects while Topping and Trickey (2007a) reported that students recorded significant standardised gains in verbal and non-verbal reasoning ability that generalised to non-verbal and quantitative reasoning ability. Furthermore, these gains were maintained when Topping and Trickey (2007b) followed these students up two-years later after they had transferred to high school even though they had not received further instruction in P4C. In summary, dialogic teaching is promoted when teachers and students cooperate, listen to each other, explain their own thinking, and engage in sustained discussion of complex ideas. The teacher in the dialogic classroom, uses more high-level questions that probe students' thinking, encouraging them to analyse and speculate on ideas and challenge different propositions with evidence. Students, in turn, listen more attentively to their teachers and students and engage in more interactions with each other. In so doing, they learn to interrogate others' claims, justify their own positions, rebut and reconcile contradictory claims as they engage critically and constructively with each other's ideas.

1.2. Purpose of the study

Given the importance of dialogical interactions in classrooms for promoting student reasoning, problem-solving and learning and the key role teachers play in fostering these interactions, the purpose of this study is twofold: first, the study aims to illustrate how three teachers engage in dialogic teaching, focusing, in particular, on the types of prompting and mediating behaviour they use to promote thinking, problem-solving and reasoning in students. Second, the study aims to provide examples of the different dialogical interactions students use as they work cooperatively together on a specific problem-solving tasks.

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2. Method

2.1. Participants: teachers and student groups

The data reported in this study were from three teachers and 17 groups of children who participated in a larger study involving seven Year 7 teachers and 42 groups of students in their classes (see Gillies, Nichols, Burgh, & Haynes, 2014). All the teachers in the larger study had agreed to teach two units of cooperative inquiry-based science across two school terms. Of the three teachers in the current study, all were from the cohort of teachers who were trained to use a dialogic approach to teaching to challenge students' thinking and learning (described below). Of the three teachers, one was male and two were female, all had been teaching for longer than 10 years, and all were regarded by their principals and peers as very professional teachers who had good content and pedagogical knowledge, enabling them to work effectively with students in their classes.

Each of the 17 student groups (10 groups for the forces and energy unit and 7 for the cells unit) were chosen at random from a pool of 24 student groups whose teachers had been trained in dialogic teaching (described below). Each group consisted of four students who had been randomly assigned by their teachers to gender-balanced, mixed-ability groups. All groups were videotaped as they worked on the specific inquiry-based science activities across two consecutive school terms.

2.2. Professional learning workshops

All teachers participated in three days of professional learning workshops which provided them with the background information on the two inquiry-based science units that they had agreed to teach (see Gillies et al., 2014). The first unit focused on how forces and energy create motion and how the motion of objects change as the result of opposing or supporting forces, how renewable and non-renewable energy sources can be identified and used, and how energy can be transferred and transformed. These investigations were accomplished by having the students design different bicycles for different purposes and offer scientific explanations of the forces, motion, and energy that operate. The second unit focused on helping students to investigate the differences between animal and plant cells, the structure of cells, the functions of the different parts, and how these different cells and their structures could be represented. The students examined different cells under the microscope and prepared specimens for the microscope to enable them to examine the different cell structures and represent them through the construction of a model. Both inquiry-based science units were implemented across an 8–10 week period.

In addition to the information the teachers received on the inquiry-based science units, all teachers received information on how to embed the key elements of cooperative learning into the inquiry activities so that students understood that they were expected to contribute their ideas, demonstrate appropriate social behaviour, facilitate each other's learning, and reflect on their own and the group's progress on the group's task (Johnson & Johnson, 2002). When cooperative learning pedagogies are embedded in classroom curricula, students learn to listen to what others have to say, share ideas, give and receive help, clarify differences, and construct new understandings from actively engaging in discussions with each other. The dialogues that occur are multidirectional as students learn to respond to explicit and implicit requests for help and to scaffold their responses to facilitate learning in others (Gillies, 2003, 2004).

The students were also expected to provide explanations and reasons for their own responses during group discussions (Gillies, 2004; Mercer, Wegerif, & Dawes, 1999). Specifically, all group members were encouraged to contribute to the discussion, actively listen to others, constructively challenge others' ideas, provide reasons for positions adopted and, reach consensus on decisions.

The three teachers in the current study received additional information and training in the specific communication skills that are designed to promote students' thinking and scaffold their learning. This included how to probe and clarify, acknowledge and validate students' efforts, confront discrepancies in thinking, and tentatively offer suggestions to help resolve problem issues (Gillies, 2004). Two of the teachers received additional information on how children can scaffold each other's thinking to progressively higher levels using the Ask-to-Think-Tel Why model of transactive peer tutoring (King, 1997). This model emphasises: reciprocal tutor–tutee roles where students of similar ability have turns tutoring each other; the use of appropriate social behaviours, and the importance of providing elaborated explanations and asking thinking questions. Students work in pairs with one student acting as a cognitive coach (tutor) who asks a series of sequenced questions to scaffold the tutee's thinking to consider progressively more complex issues and develop more elaborated responses. The students work together with each prompting the other for new ideas and perspectives so the interactions that occur are reciprocal and interdependent with each transacting on the other to construct new insights and knowledge.

The third teacher received information on how to implement Philosophy for Children (P4C), an approach to questioning that is designed to help children to interrogate information, explore disagreements, draw inferences, and make considered and rational judgments (Lipman, 1988a, 1988b). P4C uses a Socratic style of questioning which is designed to challenge children to think more independently and engage in more thoughtful dialogue as they question each other and investigate issues together. During these dialogic exchanges, the class acts as a community of inquiry where the skills of the teacher are paramount in helping students to: (a) communicate their views in response to the topic being discussed, (b) provide reasons for their views, (c) listen with respect to the views of others, and (d) indicate whether they agree or disagree. The teachers'

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role is to model and facilitate these dialogic exchanges. In short, the teachers were taught how to engage students in dialogic discussions designed to promote student interactions, thinking, and learning.

2.3. Procedure

All student groups were videotaped once for approximately an hour during each inquiry-based science unit. Both videotaping sessions occurred in the last two weeks of each science unit to ensure that all groups were discussing the same topic. As the activities that students worked on (i.e., designing a bicycle and representing a cell) were the culmination of different experiences the students had had during each science unit, teachers were asked to let each group work independently and only intervene in the discussion when they believed they needed to do so.

2.4. Coding of the teachers' dialogic interactions

The teacher's prompting and mediating behaviours in the vignettes that follow were coded according to categories originally identified by Gillies (2004, 2013) and informed by Mercer (2008), and Michaels, O'Connor, and Resnick (2008). The specific categories coded included the following: *Probes* to obtain additional information or ideas; *Challenges*: seeks basic information, asks children to consider perspectives; *Focuses* on issue: draws attention to task or problem; *Cognitive*: requires reasons; *Scaffolds connections*: links information or ideas to help children construct new knowledge; *Metacognitive*: thinking about thinking. The author initially coded the transcribed vignettes and two coders who had had extensive experience coding discourse patterns independently coded the transcripts before checking with each other and the author (blind to the coders) on the codes identified. There was 100% agreement between all three coders on the categories identified.

3. Results

3.1. Examples of teachers' dialogical interactions

In order to elucidate how the teachers prompted and mediated students' learning, a vignette is provided of the discourse three teachers used (chosen randomly from a pool of 42 h of students video data) as they interacted with students during their small group activities.

In the first vignette, Murray, the teacher, is monitoring the progress of one of the student groups in his class as they apply the knowledge they have acquired from studying Forces and Energy, the first inquiry-based science unit, to design two different types of bicycles that are suitable for different terrain. The groups are required to be prepared to identify and justify the scientific reasons for the designs they present to the whole class. The vignette below represents only a few minutes of the teacher's time with the students as he moved among groups to monitor progress and provide assistance when needed. (NB: T = teacher; S = student)

3.1.1. First teacher vignette

1. T: Where are you guys up to? Are you still making a list? (*T. focuses the students' attention on the first requirement of the task*)
2. S: Yes, we are.
3. T: How's your list going? (T. probes to elicit additional information from the group)
4. S: Pretty good.
5. T: What have you come up with? (*T. continues to probe to encourage students to elaborate on their ideas*)
6. S: How do you spell "grippy"?
7. S: "Grippy" isn't a word.
8. S: Yes it is.
9. T: What about "good traction"? "Good traction" is probably better. (*T. scaffolds the children's ideas to construct a clear understanding of the term 'grip'*)
10. S: Thank you.
11. S: I've got one. Grippy pedals.
12. S: Aren't there spokes or something?
13. S: "Make at least two drawings in your group that show the main features of your bike. You may like to work in pairs." (S. reads from text). Let's just split the page in half and do two. We'll work together. Let's draw the wheels.
14. T: Are you going to draw a bike each? (*T. focuses the students' attention on one of the requirement of the task*)
15. S: No. We're doing it together.
16. T: OK. That's fine. You can work together on your drawings. The idea is to come up with the best design you can or what qualities you can combine to make the best bike. Remember, you'll be sharing your design with the class later. (*T. scaffolds students' understandings so they can connect them together to construct the best design they can to share with the class*)

17. S: Well, why don't I try and draw the gears and you draw the wheels?
18. S: OK.
19. S: We need spokes.
20. S: Do we label these?
21. S: We label the next one.
22. S: It says to show the main features of your bike, so we'll just do those.
23. S: (Asks teacher) Sir, do we label this one with details?
24. T: No, you don't have to but you'll need to be able to explain it to each other so you might like to think about whether you should label it or not. (*T. scaffolds ideas on labelling and explaining their design*)

It is interesting to note that the teacher is minimally intrusive, only intervening in the students' discussion when he believes he needs to probe for additional information (Turns 3 and 5), focus the students' attention on the various requirements of the task (Turns 1 and 14), and scaffold students' ideas and information to construct clearer understandings (Turns 9, 16, and 24). In response, the students remain focused on the task of designing their bicycle as demonstrated by the questions they ask, the statements they make, and the suggestions they propose. Their language is respectful of each other (e.g., Thank you) and inclusive of others in the task (e.g., *Let's just split the page in half and do two. We'll work together. Let's draw the wheels: Well, why don't I try and draw the gears and you draw the wheels?*). These are verbal behaviours that Gillies (2003, 2004) found students use when they feel a sense of group cohesion and social responsibility for each other's learning; behaviours that are typically exhibited by students who work cooperatively together (Johnson & Johnson, 2002).

3.1.2. Second teacher vignette

In the second vignette, Larissa, the teacher is focusing the students' attention on the next steps in the process of designing their bicycle and the importance of developing good arguments for features they may like to include. This group, like the previous one, is completing this task from the science unit, Forces and Energy.

1. T: Just do quick diagrams. The next step is the important one where you argue for particular features. You might decide in your group just to have one person doing the illustration and the other people in the group telling this person what you want in the drawing – with a good argument of course. (*T. focuses students' attention on the requirements of the task*)
2. S: (To 1) Do you want to do the drawing? (To 3 and 4) Do you want B. to do the drawing?
3. S: Yes.
4. S: OK then. (Starts drawing)
5. S: So we have to design the bike. What's the chain?
6. S: This (pointing) is the chain. It goes to the gears.
7. T: So, what are the main features you have decided to use for your bike? (*T. probes to elicit information from the group on the main features they may need to include*)
8. S: Suspension. (short response)
9. T: What's suspension and why would you use that? (*T. challenges the student to provide a reason for why a bicycle would need a suspension*)
10. S: For rough rides.
11. S: So it's not so bumpy.
12. S: Yes.
13. T: What else is your bicycle going to have? (*T. probes to elicit additional information on the features the group may need to include*)
14. S: Gears. (short response)
15. T: What kind of gears? (*T. probes to elicit specific information on the types of gears that the group are considering*)
16. S: Ones that control your speed. You know how you can tighten it or loosen it? Like when you are going uphill you might want them a bit looser and when you are going downhill you might want them a bit tighter so that you don't fall off.
17. S: When you go higher in the gears, it makes the bike a bit harder to ride.
18. T: That's true. So, B. is starting on the final drawing? Is that going to be the final drawing, B.? (*T. probes to elicit additional information from the group*)
19. S: Yes.
20. S: They're great gears. (Points to 1's drawing)All children continue to work on their own drawings.*Teacher points to 3's drawing.*
21. T: So you've got those handlebars. What's so good about that kind of handlebars?(*T. challenges the students to provide a reason why the handlebars are appropriate for the bicycle*)
22. S: You have more grip around them and you have better control and don't fall off too early.

In the vignette above, the teacher poses a series of questions that focus the students' attention on the task at hand (Turn 1) and then probes to elicit further information or ideas on the features they will need to include in their bicycle design (Turns 7, 11, 13, and 16). In Turn 9, she challenges the students to think about why a bicycle would need a suspension to which the students respond "For rough rides" (Turn 10) and "So it's not so bumpy" (Turn 11). While these responses are correct, they are minimal informative, however, the students responses become more elaborated as the teacher continues to press for more specific information on the kind of gears required (Turn 13) to which the students respond with more elaborated information (Turns 14 and 15). In Turn 19, the teacher again challenges the students to provide a reason why they have chosen the handlebars they have and, again, the response by the student is more detailed and elaborated (Turn 20).

It is interesting to note that the teacher's questions become progressively more demanding as she moves from focusing the students' attention on the requirements of the task to pressing for specific information to requiring the students to provide reasons for the choices they have made (Turns 9, 13, and 19). These questions are more cognitively challenging and require higher-order thinking which is demonstrated by the responses given by the students in Turns 14, 15, and 20 where they clearly indicate that they understand the effect and consequences of their decisions. Challenging students to provide explanations and reasons are important if they are connect what they have learned previously to what they are currently learning and engage in more reasoned argumentation, problem-solving and learning (Gillies & Khan, 2009; King, 2002).

3.1.3. Third teacher vignette

In this vignette, Sandy, the teacher is interacting with a group of students in her class who have been participating in the second inquiry-based science unit on cells. This unit focused on helping students investigate the differences between animal and plant cells, the structure of the cells, the function of the different parts, and how these different cells and their structures could be represented. The students had examined different cells under the microscope and prepared specimens for the microscope to enable them to examine the different cell structures and represent them through the construction of a model. In this vignette, the students are developing a brochure that incorporates the structure and function of the various parts of a cell.

1. T: That's beautiful. (referring to the cell diagram)
2. S: Should we put in vacuoles?
3. T: Yes. Animal cells have small vacuoles. Absolutely. (*T. affirms student's suggestion*)
4. S: And they've got more than plant cells?
5. T: Yes, and they're involved in keeping the cells firm. You know how celery wilts after a while. Well, the water in these vacuoles help to stop that happening. (*T. uses an analogy to help the students' link previous knowledge to what they are currently learning*)
6. S: What do vacuoles look like? Are they like little holes?
7. S: They are like blobs.

The teacher, in the vignette above, is minimally intrusive as she only intervenes when the students invite her to comment on their questions as she does in Turn 3 where she affirms a student's suggestion and again in Turn 5 when she uses an analogy, a tool that Niebert, Marsch, and Treagust (2012) found helped to build bridges between students' everyday knowledge and scientific concepts. In this case, the teacher used an analogy to help illustrate the links between hydration of the vacuoles and the reaction of celery when it is dehydrated.

3.2. Summary of teachers' dialogical interactions

It is clear from the three teacher vignettes above that all teachers engage in dialogic interactions with the students in their groups, and although each does it in a slightly different way, many of the questions they pose to prompt and mediate students' thinking and learning are similar. For example, they pose questions that focus students' attention on issues, probe to elicit additional information or ideas, cognitively challenge students to provide reasons, and scaffold connections to help students construct new understandings. These questions which are open and dialogic are ways of interacting designed to help students consider alternative possibilities or perspectives, explore and evaluate ideas, argue, reason and explicate their thinking, and justify their propositions. Teachers who interact this way with their students are engaged in dialogic teaching (Alexander, 2008a, 2008b; Mercer & Littleton, 2007; Scott et al., 2006).

3.3. Coding of the students' verbal interactions

The videotapes of the students' discussions and were fully transcribed and the students' verbal interactions were coded according to categories identified by Gillies (2013). The same procedure that was used for coding the teacher vignettes was followed for the students' vignette until there was 100% agreement among all three coders on the categories identified.

The interactions that were coded from the transcripts included the following seven verbal behaviours: (a) statements are declaration or a clear expression of facts or opinions that can be accepted as reasonable, (b) challenges or rebuts involve contesting previous positions with alternative or logical explanations, (c) elaborates or explains in detail, (d) open questions designed to stimulate further discussion, (e) closed questions designed to elicit short, unelaborated responses, (f) reasons with evidence, and (g) short responses that elicit minimal responses. The student interactions that were identified in the first inquiry science unit on Forces and Energy are presented in Table 1.

Table 2 shows the percentages recorded for the different types of verbal behaviours across 10 groups in the forces and energy inquiry unit. It is interesting to note that 85–99% of the total talk that occurs in the groups can be categorised by the verbal behaviours represented in Table 1 with productive talk or talk that encourages a high level of reciprocity (i.e.,

Table 1
Types and examples of verbal interactions identified in the forces and energy unit.

Verbal interactions	Examples
Statements/declarations: clear expression of facts or opinions that can be accepted as reasonable	You've got gears on your bike. If you go home tonight and test out each gear, you'll find that sixth is the hardest gear to pedal
Challenges or rebuts: contest previous positions with alternative logical explanations	Yes, more inertia. How can we stop them? You can't exactly stop them, can you?
Elaborates or explains: provides more details about terms, links information and relationships	See aluminium's really light. If you've ever held a tin can, it's really light
Open questions: designed to stimulate further discussion or provide information	What do you think we still need to add to our diagram?
Closed questions: designed to elicit short, unelaborated responses	Is this what is needed?
Reasons: provides evidence to support a proposition or position	Yeah but then when you go up hills, you experience gravity if you have a lighter bike
Short responses	Yes! No! Perhaps?

statements, challenges/rebuttals, elaborations, open questions, reasons) ranging from 58 to 86% of total group talk. Similar results were reported by Gillies (2013) who found that 53–80% of talk in groups that had been trained to use one of three linguistic tools (i.e., cognitive questioning, Philosophy for Children or Collaborative Strategic reading) to promote discourse was productive talk involving students elaborating on ideas, asking questions, providing reasons, rebutting points, making statements, and acknowledging the contributions of others. In short, over half the total talk in the groups in these two studies (current study and Gillies, 2013) was productive talk or talk that is known to promote learning among students (Webb, 2009; Webb et al., 2014).

In order to elucidate the different types of productive talk the students engaged in during their small group discussions on forces and energy, a vignette is provided of the discourse evident in one group. The forces and energy unit that the students had been studying focused on investigating how forces and energy create motion and, in particular, how the motion of objects change as a result of the opposing or supporting forces, how renewable and non-renewable energy sources can be identified and used, and how energy can be transferred and transformed. These investigations were accompanied by having the students design different bicycles for different purposes and offer scientific explanations for the forces, motions, and energy that operate.

In the vignette below, the students' talk is predominately characterised by statements, elaborations, rebuttals or challenges, reasons, and open questions as they discuss designing a bicycle for different terrains. The students have been learning about Newton's Laws of Motion (1–3) so they often make reference to one of these laws during their discussion.

3.3.1. *Student vignette*

1. S1: Gears are for changing the amount of force you have to apply. And it's the second law. (*Elaboration on what gears do*)
2. S2: So we've got gears. You can change gears to change the amount of force you have to apply to the pedals. (*Elaboration on the function of gears and force required*)
3. S3: What else is special that we need on the bike? (*Open question to elicit additional information*)
4. S1: We would need brakes obviously. (*Statement of fact*)
5. S3: What if you have two brakes, one for the back and one for the front tire and you accidentally push the front one and you come right off the bike? (*Elaboration on potential consequence*)
6. S2: What if we thought about a new sort of bike and with the brake in a different spot to make it easier to brake and rather than just stopping one tire it stops both? (*Open question to elicit additional information*)
7. S1: Maybe you could sort of lean back. But then you might not remember to do that.

Table 2
Percentage of students' verbal behaviours in groups 1–10 (trained groups) during the forces and energy science unit.

Types of talk	1	2	3	4	5	6	7	8	9	10
Statements	21.49	18.94	46.66	24.5	21.42	13.79	23.80	22.22	22.03	21.56
Challenges, rebuts	14.47	4.72	0.00	0.00	3.57	3.44	9.51	2.22	3.38	7.80
Elaborates, explains	25.33	35.26	6.66	32.06	32.13	45.13	25.39	31.1	20.32	23.50
Questions – open	13.15	8.42	20.0	9.43	14.28	17.24	9.52	13.33	8.47	9.73
Questions – closed	8.77	7.36	26.66	9.43	7.14	3.44	11.11	2.22	13.55	5.82
Reasons	8.33	14.21	0.00	7.54	0.00	6.89	7.93	20.00	3.38	7.84
Short responses	1.75	3.15	0.00	16.98	7.14	10.34	4.76	2.22	18.64	17.64
Productive talk subtotal	82.77	86.25	73.32	73.73	71.4	82.48	76.15	88.87	57.58	70.43
Total	93.29	96.76	99.98	99.94	85.68	99.96	92.02	93.31	89.77	93.89

NB: Percentage totals did not total 100% because some language utterances were unintelligible on the videotapes or consisted of single words that could not be identified as belonging to one of the categories in the above table.

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8. S2: You could sort of make the back of the bike heavier than the front. (*Statement providing additional information*)
9. S3: Yes.
10. S2: So, make the back heavier than the front of the bike. (*Statement affirming previous idea*)
11. S1: But that would be harder going uphill. (*Challenge to previous suggestion*)
12. S3: You could take off the heavy metal.
13. S2: So, we'll just stick with the gears can be used for both tires. (*Statement of action*)
14. S1: You mean brakes? (Clarification on action)
15. S2: Yes, true.
16. S3: So we have two different brakes? (*Closed question*)
17. S1: Why not just use the back one? (*Challenge to previous speaker*)
18. S3: The pedal brake?
19. S2: Yes.
20. S3: Do we have a pedal brake? Oh yes we do too. (*Closed question*)
21. S1: I don't. I've got a BMX competition bike. (*Rebuttal indicating a pedal brake is not always needed*)
22. S2: Yeah. But we're talking about a mountain bike. (*Clarification on the topic under discussion*)
23. S1: Mountain bikes don't have that because they have gears. (*Provides reason*)
24. S3: I don't have brakes on my pedals. (*Statement of fact*)
25. S1: That's because bikes with gears don't have them. And they should. (*Reason*)
26. S2: So bikes without gears have pedal brakes? (*Closed question*)
27. S1: Sometimes. Like children's bikes. (*Analogy*)

It is interesting to note that 18 of the possible 27 responses in the vignette above involve statements, elaborations, rebuttals or challenges, reasons, and open questions, or talk that is aimed at encouraging high levels of reciprocity where each response builds on the previous one so the discussion is sustained and focused. The sense of 'group' or commitment to the task is also apparent from the frequent use of "we", denoting a level of substitutability, inducibility, and positive cathexis, the psychological processes created by positive interdependence that lead to efforts to achieve (Johnson & Johnson, 2008). Gillies (2003) found that when students work cooperatively together, they develop an understanding of the unanimity of purpose of the group and the need to help and support each other's learning and will provide help even when it is not explicitly requested. It is this willingness to help each other, share resources, and actively promote the group's learning that denotes groups whose members are more empathic, more involved, and committed to each other, and, hence, more willing to support the group's goals.

The students also completed an inquiry science unit on Cells. The student interactions that were identified in this unit are presented in Table 3.

Table 4 shows the percentages recorded for the different types of verbal behaviours across seven groups in the cells inquiry science unit. It is again interesting to note that 85–99% of the total talk that occurred can be categorised by the verbal behaviours represented in Table 3 with productive talk ranging from 66 to 89% of total group talk. In short, the percentage of productive talk across the seven groups was sustained during this second inquiry-based science unit, indicating that the opportunities the students had had to engage in dialogic interactions with their teacher and each other had been maintained, reinforcing the original training they had received in how to ask cognitively challenging questions that sought to interrogate information, investigate differences, and draw inferences before making judgements.

3.4. Summary of students' verbal interactions

It is evident from Tables 2 and 4 that the students are actively involved in the discussions in their group, making statements, explaining or elaborating on ideas or issues, posing open questions, rebutting suggestions or points, and providing reasons for positions taken. The vignette on Forces and Energy shows that their interactions are sustained with students engaged in dialogic interactions where they demonstrate a willingness to listen to others, suggests ideas, and accept

Table 3
Types and examples of verbal interactions identified in the cells unit.

Verbal interactions	Examples
Statements/declarations: clear expression of facts or opinions that can be accepted as reasonable	How about all those extra details like a plant cell has a bigger vacuole than an animal cell?
Challenges or rebuts: contest previous positions with alternative logical explanations	No. That's the chloroplast. The chloroplast contains chlorophyll as important for photosynthesis
Elaborates, explains or analogises: provides more details about terms, information, relationships	It (cell membrane) controls the entry and exit of food and it also holds the thing together
Open questions: designed to stimulate further discussion or provide information	What do you think we still need to add to our brochure?
Closed questions: designed to elicit short, unelaborated responses	No, that's outside. Isn't this place inside?
Reasons: provides evidence to support a proposition or position	It (chloroplast) could be a medical room (representation) because it's important for photosynthesis
Short responses	Yes! No! Perhaps?

Table 4
Percentage of students' verbal behaviours in groups 1–7 (trained group) during the cells inquiry science unit.

Types of talk	1	2	3	4	5	6	7
Statements	23.59	35.87	24.28	38.09	22.03	22.78	31.14
Challenges, rebuts	2.24	4.57	5.70	1.58	1.69	14.55	1.63
Elaborates, explains, Analogises	44.93	29.00	24.27	20.62	23.70	28.46	39.32
Questions – open	19.10	10.68	25.70	23.80	15.23	16.41	4.91
Questions – closed	1.12	1.52	10.00	4.43	13.55	4.43	8.19
Reasons	0.00	4.58	0.00	0.00	3.38	0.00	1.63
Short responses	8.98	13.74	10.00	10.12	18.64	10.12	13.11
Productive talk subtotal	89.86	84.70	88.53	84.09	66.03	82.20	78.63
Total	99.96	99.96	98.53	98.64	98.22	96.75	99.93

NB: Percentage totals did not total 100% because some language utterances were unintelligible on the videotapes or consisted of single words that could not be identified as belonging to one of the categories in the above table.

suggestions; building on those ideas to chain them into cogent lines of thinking and understanding (Alexander, 2008a). These are clear behavioural markers of the strength of the positive relationship that existed among group members as they worked cooperatively together.

4. Discussion

This study had two aims: first, the study aimed to illustrate how three teachers engaged in dialogic teaching; focusing, in particular, on the types of prompting and mediating behaviour they use to promote thinking, problem-solving and reasoning in students. Second, the study aimed to provide examples of the different dialogical interactions students use as they work cooperatively together on a specific problem-solving task. This study involved three teachers chosen at random from a cohort of teachers who had participated in professional development workshops on dialogic teaching. The 17 groups of students were also drawn at random from the same cohort of teachers' classes (see Gillies et al., 2014).

It was apparent from the three teachers' vignettes that all engaged in dialogic teaching with their students where they listened attentively to students questions, probed and challenged their thinking while providing them with time to respond, focused students' attention on key issues/points, scaffolded thinking to help students connect previous information to what they are currently learning, and encouraged students to explicate their reasoning and thinking.

In order to create the conditions that would encourage the students to engage in dialogic exchanges with each other, the teachers worked with the students to encourage them to listen to each other, share ideas, and consider alternative perspectives. In turn, students were encouraged to express their ideas freely, be constructive in their feedback to group members, and build on the ideas of others; linking what they already knew with what they were learning (Alexander, 2008a). If classroom talk is to be open and dialogic, it needs to be well planned and structured with specific learning goals clearly identified. Gillies (2004) found that when teachers are trained to use specific communication skills designed to promote students' thinking and scaffold their learning, not only do they use more mediated-learning interactions than their untrained peers but the students in these teachers' classes, in turn, model many of their teachers verbal behaviours and provide more detailed explanations and ask more questions than students in the untrained teachers classes; demonstrating clear complementarity between teachers' and students dialogic interactions.

The importance of structuring classroom talk to promote dialogic exchanges and learning was demonstrated by Engle and Conant (2002), Gillies (2003, 2004), Resnick, Michaels, and O'Connor (2010), Mercer, Wegerif, and Dawes (1999), and Topping and Trickey (2014) who found that structured, dialogic exchanges support enhanced disciplinary knowledge and reasoned argumentation.

An examination of the different dialogic interactions that occurred in the 17 student groups showed that 57–89% of the total exchanges involved students making statements, challenging and rebutting, asking questions, speculating, and reasoning and justifying particular propositions. Moreover, the exchanges were sustained and intense as the groups worked with a common purpose to resolve the problem at hand, albeit designing a bicycle for different terrains or representing the different parts of a cell. In short, it was apparent that the students had accumulated an inventory of linguistic tools or ways of talking that they drew upon to respond to others questions, statements, reasons, challenges, and propositions.

A definite commitment to the group and the task they were completing was evident from students' willingness to involve others in their discussions, to engage in sustained exchanges about a topic, and to build on each other ideas and substitute the ideas of others when they were perceived there was value in doing so. Johnson, Johnson, Roseth, and Shin (2014) found that when a state of positive interdependence exists, as occurs when students cooperate, they are more motivated to achieve than when they compete or work individually on a task.

4.1. The teacher's mediating role in students' learning: implications for teaching

Recent research has highlighted the key role teachers play in mediating students' learning by creating opportunities for students to engage in dialogic exchanges with their teacher or each other so they learn to ask questions, explore and evaluate ideas, argue, reason, and explain propositions, and negotiate solutions to problems at hand (Alexander, 2008a; Mercer & Littleton, 2007). In fact, Webb (2009) argued that the teacher's role in fostering beneficial group dialogues is multifaceted and involves preparing students to work together, structuring the group task, and influencing student interaction through the teacher's discourse. Strategies that Webb found teachers used that nearly always produced further student explaining and often resulted in groups providing correct and complete explanations for solving problems included probing students thinking so they provided further details about their problem-solving strategies, using students initial explanations to drive their probing questions, persisting in asking questions to help students clarify any misconceptions or abstruse explanations, and ensuring that they refrained from injecting their own thinking into their probing questions. Webb et al. (2014) found that students who engaged with and built on others' ideas, showed higher achievement than students who did not do this. Furthermore, when teachers pressed students to make their thinking explicit, it helped them to reflect on their own ideas in the light of others' ideas and, in so doing, enhance their own understanding and thinking. In short, teacher follow-up on their initial moves to probe students' thinking and clarify their understandings, is critically important if students, in turn, are to engage with others' ideas and learn.

5. Conclusion

There is no doubt that talk by teachers and peers has the capacity to stimulate and extend students' thinking and advance their learning. Teachers do this when they engage in dialogic teaching practices where they actively listen to students, probe, challenge, and scaffold their understandings while encouraging them to explicate their reasoning and thinking. In turn, students engage in dialogic exchanges when they listen to others, share ideas and challenge alternative propositions while being prepared to substitute others' ideas for one's own when there is value in doing so. It is the recursive nature of these dialogic exchanges that Michaels, O'Connor, and Resnick (2008) argue contributes to academically productive talk.

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