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Discourse forms in a classroom transitioning to student-centred scientific inquiry through co-teaching

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ABSTRACT

Teacher–student discourse continues to be teacher-centred even though researchers and reform documents have recommended changes toward increased levels of student-centred discourse. In science education this situation is paralleled by effort to make scientific inquiry more student-centred. The purpose of this study was to investigate how discourse forms changed over time in a classroom where the regular teacher and his students were scaffolded in the transitioning to student-centred scientific inquiry. Video-recordings were collected at intervals over one academic year. Three prominent forms of discourse were identified: two teacher-authoritative forms and one more interactive, dialogic form. As the lessons increasingly turned into student-centred scientific inquiry, a shift to the dialogic discourse form was found. Co-teaching provided for (a) guidance towards an organisation of events in the classroom that included regular teacher–student dialogue (b) modelling of the more dialogic form of discourse.

Introduction

There now is abundant evidence that the best environments for learning incorporate teacher–student discourse that is more student-centred, where students are given ample opportunities to contribute (Resnick, Asterhan, & Clarke, 2015). The theoretical foundation lies with Vygotsky (1978) who indicated the importance of language and socio-cultural interactions to human development and learning. Although great efforts have been made to promote more student-centred discourse (Mercer & Dawes, 2014), an over-reliance on teacher-dominated discourse forms remains the norm in classrooms (Alexander, 2015). Examples of teacher–student discourse forms from this study illustrate differences between these two types.

Teacher–student discourse forms

A. Teacher-dominated discourse	B. Student-centred discourse
Teacher: stage two sprout what is stage one	Teacher: Okay what happened what did you change
Laura: seeds	Jane: Um me and Laura we changed the string
Teacher: Right what is stage two Emma	Teacher: Okay
Emma: sprout	Jane: With it thicker
Teacher: sprout everybody	Teacher: Thicker string hey (writing on a sticky note)
Students: sprout	Jane: Yeah and it still worked
	Teacher: Oh Yeah
	Jane: (Nodding)
	Laura: And we put our finger through we actually did it

Examples of teacher dominated and student-centred discourse forms from this study are shown above: the teacher-dominated discourse example occurred during a lesson about the stages of the life cycle of a pumpkin; the student-centred discourse example occurred when students and the teacher were talking about students' experiments called 'magnetic kites' where they used a magnet to raise a paper clip attached to a string. Without touching the paperclip, the magnet could move it around in the air so that it resembled a kite. Students had chosen one variable to change, and had conducted experiments to find out what happened. They are talking with the teacher about the variable they changed, and about what happened.

In the teacher-dominated example, the teacher does most of the talking, asking questions to which s/he already knows the answer and students' responses are of one or two words. In the student-centred discourse example, the teacher asks an open-ended question and the students do most of the talking, articulating ideas about what they have done and what they think.

In this study, we do not judge the forms of discourse as inherently good or bad; both student-centred and teacher-dominated discourse forms co-exist in classrooms environments that support student learning (Alexander, 2006; Mortimer & Scott, 2003; Scott, Mortimer, & Aguiar, 2006). Each discourse form has a function or distinct purpose that is appropriate in a particular type of situation (Mortimer & Scott, 2003; Roth, McGinn, Woszczyna, & Boutonné, 1999; Scott et al., 2006). However, we do advocate for more opportunities in classrooms for student-centred discourse.

Efforts to promote student-centred discourse are paralleled in science education by efforts to make scientific inquiry practices in classrooms more student-centred (e.g. Next Generation Science Standards, 2013; Rocard Report, 2007; Tytler, 2007). Scientific inquiry refers to the particular practices of observing, thinking, investigating and validating that scientists use in their work (American Association for the Advancement of Science [AAAS], 1993). In student-centred scientific inquiry, students take a substantial role in developing, conducting and communicating their scientific inquiries (e.g. Next Generation Science Standards, 2013; Rocard Report, 2007; Tytler, 2007). The context of the present study is a professional learning opportunity for teachers to develop student-centred scientific inquiry practices in their classrooms. Anecdotal evidence suggested that discourse forms between teachers and students were changing over the course of this professional learning. The purpose of this study is to specifically focus on teacher–student discourse forms and how they change over the course of the professional learning opportunity whose main purpose was to promote student-centred scientific inquiry.

Professional learning opportunities for student-centred scientific inquiry have traditionally occurred outside the classroom and transfer of these learning experiences to practices inside classrooms has proven to be difficult (e.g. Blanchard, Southerland, & Granger, 2009; Enderle et al., 2014). The Steps to Inquiry project that is the context for this study aims to bypass this transfer problem by introducing teachers and students to student-centred scientific inquiry together in their own classrooms, through co-teaching with a master teacher. In co-teaching two or more teachers work together in the classroom taking joint responsibility for student learning (Roth & Tobin, 2002). Co-teaching in the context of this study is a form of embedded professional learning (Darling-Hammond & McLaughlin, 1995; Hirsh & Killion, 2009), where teachers' learning is situated within everyday practice. A teacher learns 'at the elbow' of a master teacher in the realities of everyday practice with students (Roth, Masciotra, & Boyd, 1999). Studies of co-teaching have shown that teachers appropriate practices without having to bring these into awareness, that is, teachers learn in tacit modes (Roth, 1998).

The research questions addressed are: 'How do teacher–student discourse forms change over the course of a year in a classroom that is part of the Steps to Inquiry project?' and 'How do changing discourse forms arise in and from co-teaching?'

Background

Teacher-dominated discourse forms

Early sociolinguistic studies investigating classroom discourse demonstrated that the most common speech act sequence in classrooms consisted of a triple sequence including *i*nitiation, *r*eply, and *e*valuation (I-R-E) (Mehan, 1979). The particularity about the sequence was its unequal distribution over teachers and students. Thus, the I-R-E sequence was associated with the order teacher–student–teacher. This form was also found to be most common in science lessons (Lemke, 1990). An example of the I-R-E form can be seen in Sequence 2 in the following two sequences from a science classroom in our study.

Sequence 1: Turn 1: A: What's a variable again? Turn 2: B: Something that can change. Turn 3: A: Oh yeah, thanks.

Sequence 2: Turn 1: A: What's a variable again? Turn 2: B: Something that can change. Turn 3: A: That's right, something that can change. Well done!

The distinctiveness of the I-R-E form is indicated in the third, evaluative turn. Sequence 1 and Sequence 2 are identical in the first two turns, but in the third turn the sequences differ. In Sequence 1, speaker A thanks speaker B for providing the necessary information, but in Sequence 2 (the I-R-E form that is so common in classrooms) speaker A *evaluates* the answer provided by Speaker B by saying 'that's right' and congratulates Speaker B for providing the correct answer, by saying 'well done!' It is clear that in Sequence 2, rather than asking the question in turn 1 to find out information, Speaker A asks the question to find out *if Speaker B knows* the information; for Speaker A, the question is a known-answer question (Mehan, 1979).

The I-R-E discourse form continues to dominate teacher–student discourse. Although it does have its uses, sociolinguists agree that overuse of this discourse form in classrooms

presents a barrier for student learning (Cazden, 2001; Mercer & Dawes, 2014). It limits students to speaking only when answering test questions that teachers provide and evaluate; it presents a situation where teachers talk on average two-thirds of the time; it prevents students from deciding when to speak; it inhibits students from speaking to each other directly; and it does not provide for self-evaluation or peer-evaluation. It has also been suggested that this discourse form leads to the canonisation of scientific knowledge (van Eijck & Roth, 2011).

A second related, teacher-dominated discourse is characterised by choral responses, where the whole class responds together as a group (Pontefract & Hardman, 2005). In these studies, the choral response was most often used for reinforcing knowledge provided by the teacher in a transmission style approach. The practice of prompting children to complete a sentence was common, through such strategies as omission of the final word (Pontefract & Hardman, 2005). Manuals for primary school teachers in the 1980s recommended this approach to instruction as part of the teacher's repertoire (Rosenshine, 1983). In such manuals, the choral response was seen as suitable for re-enforcing knowledge such as decoding, wordlists and number facts. Like I-R-E this discourse form has its uses, but overuse presents the same barriers for students' learning that have been described for the I-R-E discourse form.

Student-centred teacher–student discourse forms in classrooms

In contrast to teacher-dominated discourse forms, in student-centred discourse forms teachers tend to invite students to respond to open-ended questions (Alexander, 2006; Nystrand et al. 2003) creating a cumulative discourse pattern. This form has been described as I-R-F-R-F-, where F is short for Feedback (Mortimer & Scott, 2003). The different parts of this form (I, R, F) typically fall to individuals differentially located in the school hierarchy. Thus, the teacher initiates (I) with an open-ended question such as 'can you give me an example', which is followed by the student's response (R), the teacher provides feedback (F), this leads to a further response from a student (R), leading to further feedback from the teacher (F). Chains of dialogue flow and are cumulative (Alexander, 2010), where responses are followed and built upon.

In this study, we investigate teacher–student discourse forms and how they change in the context of a co-teaching professional learning experience for teachers in student-centred scientific inquiry.

Co-teaching

In co-teaching two or more teachers work in the classroom taking responsibility together for student learning (Roth & Tobin, 2002). Co-teaching is used extensively in inclusive education as a way for teachers to share expertise for the benefit of all students (e.g. Friend, Reising, & Cook, 1993; Harbort et al., 2007; Pancsofar & Petroff, 2016). Co-teaching is also used for professional learning in initial teacher education (e.g. Murphy, 2016; Roth & Tobin, 2002; Tobin, 2006) and in-service teacher education (e.g. Roth, Masciotra, et al., 1999). Although it is co-teaching for professional learning that is the context of this study, it is important to briefly describe co-teaching in inclusive education, since much knowledge has been gained from research about how teachers share teaching in these contexts.

In inclusive education contexts there are various ways that teachers interact in co-teaching. Five ways of interacting have been characterised as follows: one teach, one assist; station teaching; parallel teaching; alternative teaching; and team teaching (Friend et al., 1993). In 'one teach, one assist,' the classroom teacher leads the class while the special education teacher assists students with exceptionalities as needed. In 'station teaching,' the teachers take turns leading specific curriculum. In 'parallel teaching,' teachers plan collaboratively but work separately in parallel with groups of students. In 'alternate teaching,' the general classroom teacher works with most of the students while the special education teacher works with a small group. It is only in team teaching (as defined by Friend et al., 1993) that the two teachers plan together and share an equal role in instruction. This form of co-teaching is seen as most effective, but it is also seen as most rare (e.g. Harbort et al., 2007; Pancsofar & Petroff, 2016).

In initial teacher education three elements have been identified as of great importance in co-teaching; co-planning, co-practice and co-reflection (Murphy, 2016). In co-planning, teachers share expertise to plan learning opportunities for students; in co-practice, teachers share responsibilities for students' learning opportunities; and in co-reflection, teachers reflect on what went well and what needs to change for next time.

The importance of co-reflection and co-planning aligns with previous work on co-teaching in science education (e.g. Roth & Tobin, 2002; Tobin, 2006; Tobin & Roth, 2005) where co-teaching is coupled with co-generative dialogue. During co-generative dialogue, co-teachers reflect and plan with the intent to design changes that they later implement. A novice teacher or a teacher new to a particular learning environment participates with a master teacher in a collective praxis that allows the novice to appropriate actions that they did not have previously in their repertoire (Roth, Tobin, Carambo, & Dalland, 2004). It is important to emphasise that in co-teaching both teachers learn (Murphy, 2016; Roth, Masciotra, et al., 1999). The model of co-teaching for professional learning used in this study draws upon this prior research on co-teaching for professional learning in science education (e.g. Murphy, 2016; Roth & Tobin, 2002; Tobin, 2006; Tobin & Roth, 2005).

Methods

Study setting: the steps to inquiry project

The setting of this study is the Steps to Inquiry (SI) project, designed to support teachers and students transitioning to student-centred scientific inquiry together in their own classroom through co-teaching with a master teacher. The SI project took place at an elementary school in a small city in Western Canada. This public K–6 elementary school was a school of choice for families whose children wanted to focus on science and technology. The school had a teaching philosophy that was inquiry-based. Due to its location in the city, the school also served a high proportion of low-income families.

Participants

The master teacher, Mr Wise (all names are pseudonyms), had a bachelor degree in science, a master's degree in education, and had worked at the school for eight years. He had been conducting student-centred scientific inquiry for four years in his own

classroom. In the Steps to Inquiry project, Mr Wise supported other teachers and their students learning to conduct student-centred scientific inquiry by joining the class and acting as a master teacher in a co-teaching format. This study focuses on one classroom in the Steps to Inquiry project: Mr Holmes' first-grade class. Mr Holmes had chosen to be part of the project due to his interest in student-centred scientific inquiry. The 17 children in the study included nine girls and eight boys. The children ranged from six to seven years of age; and this was their first introduction to student-centred scientific inquiry. Invitations to participate in this study followed university research ethics board guidelines.

Model of co-teaching

The model for co-teaching in the Steps to Inquiry project used a gradual release of responsibility format (Pearson & Gallagher, 1983) that took place in four stages. Both teachers designed the activities together to introduce scientific inquiry and to be relevant to the curriculum and the interests of the students in Mr Holmes' first-grade class (Table 1). The teachers met regularly to debrief and plan.

In stage 1 (October) Mr Holmes conducted the class in his familiar ways. He chose pumpkins and life cycles as topics in science (in autumn, pumpkins have special significance in Canada). For another topic he chose dinosaurs because of children's interests and some materials that he had to share. Outside class, Mr Wise and Mr Holmes worked together to plan and prepare student-centred scientific inquiry units on their topics for stages 2–4.

For stage 2 (November), Mr Wise led the class with Mr Holmes assisting him. Mr Wise and Mr Holmes chose the topic of motion. The unit involved scientific inquiries concerning the movement of a marble down a ramp. The teachers and students followed steps laid out in the SI framework. Over the course of three classes on three separate days of one week, students made observations, developed testable questions, and designed and conducted experiments in small groups. For stage 2, the equipment prepared included a set of identical marbles, ramps and blocks for each group, and a range of additional equipment to accommodate choices that groups might make for variables to alter in experiments (such as marbles of different sizes, ramps of different lengths and blocks of different sizes) and the SI framework posters and student booklets with identical graphic organisers (Youth Science Canada, n.d.).

Mr Wise and Mr Holmes chose to continue with the topic of motion for stage 3 (January) and this time the activity used cars and tracks. The track was taped to a desk and the car rolled down the track. Similar to their process before, they first gathered materials – this time tracks and cars; identical equipment for each group and a range of sizes and shapes of cars, a variety of lengths, widths and materials of track and a variety of materials for the car to land on, after it travelled down the track. The class worked through a second inquiry guided by the SI framework. Students again made observations, developed testable questions, designed and conducted their experiments in small groups.

Table 1. Science activities and teachers leading the class in each of the four stages.

Stage	Teacher leading the class	Science Activity
1	Mr Holmes	Traditional classes – Topics: Pumpkins, Life Cycle, Dinosaurs
2	Mr Wise (assisted by Mr Holmes)	SI Framework Supported Science Inquiry– Marbles and Ramps
3	Mr Holmes (assisted by Mr Wise)	SI Framework Supported Science Inquiry – Cars and Tracks
4	Mr Holmes	SI Framework Supported Science Inquiry – Magnet Kites

In stage 4 (February) Mr Holmes led the class alone, conducting scientific inquiries using the SI framework. He and Mr Wise had developed the unit together on the topic of magnets. 'Magnetic Kites' involved using a magnet to raise a paper clip attached to a string into the air. Without touching the paperclip, the magnet could move the paper clip around in the air so that it resembled a kite. Similar to their process before, the teachers gathered materials – this time magnets, paper clips, and string; identical equipment for each group and a range of sizes and shapes of magnets, paper clips and a variety of types and lengths of string. The students worked through a third inquiry with the SI framework. They again made observations, developed testable questions, designed and conducted their experiments in small groups.

The Steps to inquiry *guiding framework*

In their planning and teaching Mr Wise and Mr Holmes used a guiding framework referred to in this study as the Steps to Inquiry (SI) framework. Created by a team of teachers in Ontario, and based on work of Buttemer (2006) and Goldworthy and Feasey (1997), this freely available framework (Youth Science Canada, n.d.) guides student-centred scientific inquiry with a series of interactive posters (Rees, Pardo, & Parker, 2013).

The SI framework centres students' scientific inquiries on a beginning hands-on activity (such as rolling a marble down a ramp). Students complete the activity collecting observations that they share as a whole class, for the teacher to record on sticky notes and place on a poster. The students return to the activity, this time developing 'wonderings' about it, which they share for the teacher to record on sticky notes and place in a position on the poster. Then the students examine their activity set up and come up with ideas of what they could change or vary and what they could measure about it. They share these ideas, which the teacher collects on sticky notes and adds to the third position on the second poster. Then, each pair or small group of students is asked to choose one thing from the poster they would like to change (such as the size of the marble), one thing they would like to measure (such as how far the marble travels on the floor). By moving the appropriate sticky notes to new positions on a third poster, the teacher demonstrates the phrasing of a testable question for an experiment, such as; 'If I change the *size of the marble* what will happen to *how far it travels on the floor*'; and the variables that must remain the same, such as the *length of the ramp* and *type of surface*. Students then phrase their own testable question and identify the variables that must stay the same. Finally, they perform their experiment to address their question and share their findings with the class.

Data sources and collection

This study focused on classroom talk observed in video and audio recordings collected at each of the four stages of the co-teaching format. Video recordings aimed to permit the detailed description of teacher–student interactions and conversational turn-taking that occurred. Three cameras were operated simultaneously, along with voice recorders, allowing the collection of cross-sectional data. Following existing recommendations for data collection (Roth & Hsu, 2010), two fixed cameras captured the whole class from different perspectives during whole-group work, whereas the third (hand-held) focused on the teacher. Audio recorders were carried by the teachers and set on student tables to capture dialogue missing on the video recordings.

All relevant written documents (artefacts) that participants engaged with during activities were photographed. For analysis of video recordings and audio recordings, the researchers completed *verbatim* transcription as soon as possible following the events.

Data analysis

In this study, we drew upon interaction analysis (Jordan & Henderson, 1995) and conversation analysis (Sacks, Scheloff, & Jefferson, 1974) to address the research questions 'How do teacher–student discourse forms change over the course of a year in a classroom that is part of the Steps to Inquiry project?' and 'How do changing discourse forms arise in and from co-teaching?' To address the first research question initially the team of researchers examined video recordings together while reading transcripts to identify recurring discourse forms, and locating their position on the video. Then the frequency of the different discourse forms was determined for each of the stages (Table 1) of the co-teaching format. To determine the relative frequency of the three discourse forms at each stage, we counted number of turns comprising each discourse form and then expressed this as a percentage of the total number of turns comprising all three discourse forms together. A chi-squared statistical analysis was performed on the frequency data.

More detailed analysis followed of examples of each form, using detailed transcription (cf. Atkinson & Heritage, 1984). This included notation of the following: overlapping speech, intonation, pause, speech volume, and non-verbal activity. This analysis resulted in an in-depth description of these examples of each of the discourse forms identified.

To identify events or situations going on in the classroom when discourse forms emerged, we created 'event maps' (Crawford, Kelly, & Brown, 2000) of all video recordings. The event maps were chronological representations of the video recordings. We constructed running records of when particular activities began and ended by indicating the time when a change in activity occurred and noting a brief description of the activity. The maps allowed us to identify events and subevents that occurred in the classroom, such as when the students engaged in large group and small group activities, whole class introductions to scientific inquiry activities, hands-on with scientific inquiry activities (such as collecting observations, developing wonderings, identifying variables and completing experiments) and whole class sharing following these scientific inquiry activities.

To identify episodes during co-teaching where the master teacher stepped in when the classroom teacher was leading the lesson, the team of researchers examined the video recordings together while reading transcripts and located the position of these instances on the video. More detailed transcription and analysis followed as described above (cf. Atkinson & Heritage, 1984).

Validity and reliability

In interaction analysis, the researchers get together to jointly analyse video data. In these sessions, no speculations are allowed concerning the possible contents of the minds of those shown in the video. Instead, any claim has to be supported by clearly visible evidence available to every participant in the analysis session. Conversation Analysis allows us to uncover change in the structure and dynamic of conversational patterns that emerge. It aims to reveal the organisation of talk not from any outsider's viewpoint but from the perspective of participants. Conversation analysis follows how agents in a conversation take

up what has been done and said. In this way, it reveals participants' interpretations of what has been said rather than those of the analyst. Conversation analysis rigorously demands empirical descriptions to be accepted as valid (Roth & Hsu, 2010). Video recordings and the transcripts of them provide detailed and publicly available representations of talk-in-interaction. The transparent nature of the analysis allows for interpretations to be 'traceable and repeatable' by other researchers, thus increasing their reliability. Internal validity of conversation analysis is increased by the elaborate detail of the notation and the refusal on the part of researchers to interpret transactions according to a priori theory.

Findings

This study addressed two main research questions: 'How do teacher–student discourse forms change in a classroom that is part of the Steps to Inquiry co-teaching professional learning project?' and 'How do changing discourse forms arise in and from co-teaching?' To address the first research question, we identified forms of discourse found in Mr Holmes class and we determined the frequencies of each form at each stage throughout the year (Table 2).

Changing forms of classroom discourse

To determine the relative frequency of the three discourse forms at each stage, we counted number of turns comprising each discourse form and then expressed this as a percentage of the total number of turns comprising all three discourse forms together. A statistical analysis was conducted comparing stage 1 with stage 4, which corresponds to a 'before' and 'after' the co-teaching professional development for Mr Holmes. The results – χ^2 (2) = 273.78, $p < .0001$ – confirm a significant shift of turn-taking routines observed in this classroom before Mr Holmes started to teach with Mr Wise and after completion.

In the following, we describe and analyse the forms of discourse that predominated in the classroom at the beginning of the change process, when Mr Holmes was teaching alone ('Before') and the form of discourse that predominated at the end of the change process ('After'). Rather than being randomly dispersed throughout all situations in the classroom, each discourse form occurred in a distinct situation and these situations are described.

Predominant discourse forms 'Before'

Findings indicate that introduction of scaffolded student-centred scientific inquiry led to a major shift in the frequency profile of discourse forms used in the classroom. Before joining the co-teaching for professional learning project, two teacher-authoritative forms predominated in Mr Holmes class: prompt-chorus and initiate-respond-evaluate. In this section, these forms are presented in relation to the distinct situation where the forms emerged.

Table 2. Frequency of discourse forms.

Discourse Form	Number of turns per stage (%)			
	1	2	3	4
Prompt-chorus	232 (42)	2 (0.7)	12 (5)	8 (2)
I-R-E	204 (37)	84 (28)	32 (15)	94 (26)
I-R-A	111 (20)	212 (71)	176 (80)	250 (71)
Total	**547**	**298**	**220**	**352**

Prompt-chorus. Excerpt 1 is an example of the prompt-chorus pattern. This particular example occurred during stage 1 before Mr Wise joined the class. Mr Holmes was reading to the class. The topic of the book concerned the five senses and how parts of the body are used to sense and make observations.

Excerpt 1

I	01	Mr Holmes	The doorbell says 'ding dong', this doorbell looks like a speaker like that, hang on. I hear the doorbell. I hear with m:y: (*points to ears*) (..)
→ R	02	Class	Ears] 　[Ears 　　[Ears 　　　[Ears
I	03	Mr Holmes	I see a van out at the front. I see it with m:y:: (*points to eyes*) (..)
→ R	04	Class	E:y:e::s] 　[Eyes 　　[Eyes

In this manner, teacher and students moved through the story. An initiation (turns 1, 3) is paired with the articulation of a single word on the part of several students. In the initiation turns there are pauses at a particular part of the sentence such as before the name of a part of the body (e.g. ears, nose, hands, eyes) or the name of an object (e.g. pizza) and pointing or gesturing to that part of the body or picture of the object. The chorus of responses treated the preceding turns as prompts. In this joint work, students named that part of the body or the object in the picture to which Mr Holmes was pointing. Other frequent examples of the use of the prompt-chorus form occurred when Mr Holmes pointed to words or letters on a poster while pausing, and when he prompted the class by asking them to repeat a word that he had just spoken.

The distinct situation when the prompt-chorus form arose was oratorical, like the situation that occurs outside classrooms when an audience interacts with a public speaker or entertainer (Bull, 2016). The teacher acted as an orator prompting the audience (the students) in a variety of ways and then pausing for a collective audience response consisting of words and facts. The prompt-chorus discourse form is a teacher-dominated discourse form. It provides little opportunity for students to contribute to discourse, in this study, students' responses were usually limited to one or two words.

Initiate-respond-evaluate. Initiate-respond-evaluate (I-R-E) was present before and after introduction of scaffolded student-centred scientific inquiry and was used by both teachers. Excerpt 2 is an example that occurred in stage 1 (October) before introduction of scaffolded student-centred scientific inquiry. It occurred during a lesson about the stages of the pumpkin life cycle.

Excerpt 2

(I)	01	Mr Holmes	Stage two sprout (.) what is stage one↑
(R)	02	Ann	Seeds
(E,I)	03	Mr Holmes	Right (.) what is stage two (.) Emma
R	04	Emma	Sprout
E, I	05	Mr Holmes	Sprout (.) everybody
R	06	Students	Sprout

The fragment is composed of two overlapping I-R-E turns, where turns 3 and 5 evaluate the preceding reply either with an affirmative (turn 3 –'right') or by repetition of the reply (turn 5–'sprout').

The situation from which discourse form Initiate-Respond-Evaluate (I-R-E) emerged in our study were similar to previous descriptions in the literature (Cazden, 2001; Lemke, 1990; Mehan, 1979; Mortimer & Scott, 2003). This situation involved the testing of recall, where the teacher invited a student to answer a question to which the teacher already knew the answer. The I-R-E discourse form is a teacher-dominated form. As previously described in the literature (e.g. Cazden, 2001; Lemke, 1990; Mehan, 1979) the I-R-E form provided little opportunity for students to contribute to discourse, their responses being usually limited to one or two words.

Predominant discourse form 'After'

In the course of working with Mr Wise in the co-teaching for professional learning project, the turn-taking routines that the class and Mr Holmes produced increasingly were of the *initiate-respond-acknowledge* type.

Initiate-respond-acknowledge

Excerpt 3 is an example of the initiate-respond-acknowledge routine that took place in stage 4 (February) when Mr Holmes was teaching alone, having completed his professional learning through co-teaching with Mr Wise. In the excerpt, the students had just finished their magnetic kites experiments with magnets, paper clips and string, where they had chosen one variable to change, to find out what happened. In the exchange between Mr Holmes and Jane and Laura, an account is produced about what they did in the experiment and what they found out.

Excerpt 3

	(I)	01	Mr Holmes	Okay (.) What happened what did you change
	(R)	02	Jane	Um me and Laura↑ we changed the <u>string</u>
→	(A)	03	Mr Holmes	Oh [okay
	(R)	04	Jane	[with it thicker
→	(A)	05	Mr Holmes	Thicker string hey (*writing on a sticky note*)
	(R)	06	Jane	Yeah and it still worked
→	(A)	07	Mr Holmes	Oh yeah↑
			Jane	[(nodding)
	(R)	08	Laura	[And we put our finger through we a:ctually did it
→	(A)	09	Mr Holmes	Wo:a
	(R)	10	Laura	=It stayed up
	(R)	11	Jane	=Yeah it still worked
→	(C)	12	Mr Holmes	Okay good to hear↑ (*writing on sticky note and attaching to poster*) Did it work ah at the <u>same</u> <u>distance</u> <you know what I mean> (*indicating distance with finger and thumb*) so if you had the smaller string and you held the magnet to the paper clip and it was about this far away↑ (*indicating distance with finger and thumb*) was it about the <u>same</u> do you think↑ (.) or did you have to hold the magnet a little bit closer↓ or [maybe it was even better
	(R)	13	Jane	[We just put it like (*indicating distance with finger and thumb*) put it a little [bit
	(R)	14	Laura	[A little bit closer
	(R)	15	Jane	=(*nodding*)
→	(C)	16	Mr Holmes	You had to have it a little closer maybe↑ (*writing on a sticky note*)
	(R)	17	Jane	(*nodding*)
		18	Laura	(*nodding*)
→	(A)	19	Mr Holmes	Yeah (.) okay (*writing*)

There are two distinctive features related to the initiate-respond-acknowledge discourse form. First, the third turns functioned as acknowledgements (**A**) rather than evaluations, leading students to continue and take another turn. Second, there were clarification questions (**C**) that led to extensions of the student-produced turns leading to further elaboration or explanation.

In relation to the first feature, this excerpt contains five acknowledgment turns, four of which are associated with further elaborations (turn 3, 5, 7, and 9) and one that also ends the exchange (turn 19). The function of a turn always is given by the turn that follows, which makes public the effect that the preceding turn has had. Inspecting turns 4, 6, 8, and 10 reveals that all constitute elaborations. Thus, turn 3, 5, 7, and 9, function both as acknowledgments and as invitations to continue. As a result, a build-up occurs, where an initial I-R- routine is not terminated by an evaluation (to form an I-R-E sequence) but the acknowledgment (A) functioned as elicitation of another student turn (R) that adds to the already provided reply yielding I-R-(A-R-). This can be seen in the example in excerpt 3 where the telling of Jane and Laura's story about their experiment was a combined effort between Jane and Laura, who had the major role with the longer turns (turns 2, 4, 6, 8, 10 and 11), and Mr Holmes', whose turns that were single words of acknowledgement or repetitions (turns 3, 5, 7, 9 and 12).

With regard to the second feature of the I-R-A discourse form, in the example in excerpt 3, the presence of a clarification question and response turn pair can be seen in the {turn 12 | turn 13} pair. Turn 12, treated as a question in turn 13, led to the elaboration of a specific aspect of the experiment. Inspection of turn 12 shows that it directly takes up an issue articulated in the preceding turn, thereby acknowledging it and marking it as a point of interest. Because the turn takes the form of a question, and is treated in this form in the reply given (turn 12), the function of the turn was to solicit a specific elaboration rather than the open-ended one that a simple acknowledgment (e.g. 'Oh okay', turn 3; or 'Oh yeah', turn 7) would achieve.

The two features of the I-R-A discourse form together led to a chain of the type I-R-(A-R-) (Q-R-) (A- …). This provided ample opportunities for students to contribute. This discourse form occurred in stages 2–4 during sharing situations where the teachers collected students' responses to open-ended questions, without judgement, writing down their responses on sticky notes (e.g. excerpt 3: turns 5, 12 and 19) and sharing for everyone to see on posters that were on the wall. In the next section we focus on how the change in discourse forms came about through the co-teaching for professional learning project.

How the change in discourse forms came about

To address the second research question '*How do changing discourse forms arise in and from co-teaching?*' We examined video recordings to find out in what ways did co-teaching with Mr Wise in the professional learning project support the change in discourse forms in Mr Holmes classroom. Findings indicate that this occurred in two main ways: first, indirectly, when the teachers worked together to create the situations from which the discourse form emerged; and second, directly, when the teachers interacted

together with the students in these situations to create of the I-R-(A-R-) (Q-R-)(A- …) discourse chains.

The organisation of events

Event mapping (Crawford et al., 2000) of activities in Mr Holmes classroom revealed a sequential organisation of events in stages 2–4 that included frequent and regular sharing periods. The sequence was first apparent when Mr Wise led the class with Mr Holmes assisting in stage 2 of the four-stage co-teaching model, when the class was conducting the marbles and ramps inquiry. In stage 3 when Mr Holmes was the lead teacher and Mr Wise was assisting with the tracks and cars inquiry, the organisation of events was maintained. The organisation of events was still maintained when Mr Holmes was teaching alone in stage 4, when the class was conducting the magnetic kites inquiry. The organisation of events from stage 2 (November) is shown in Figure 1. A similar organisation was found in stages 3 and 4.

The sequence of events had a three-part repeating pattern. This three-part pattern occurred four times in stage 2 (Figure 1) when Mr Wise was leading the lessons and Mr Holmes was assisting. Each of the four iterations of the three-part pattern centered on an open-ended, hands-on task that students performed in pairs. The four tasks were as follows: making observations; developing wonderings; identifying variables; and conducting an experiment. Each repeating pattern included three periods: a group introduction to the open-ended hands-on task (e.g. making observations); a period when students performed the open-ended hands-on task in pairs; and finally a sharing period where students shared or reported what they found out and the teachers wrote their findings on sticky notes and posted them on the posters (e.g. sharing their observations). It was within these sharing periods that the I-R-A discourse form emerged.

As well as modelling this organisation of events when he was the lead teacher in stage 2, Mr Wise in stage 3, stepped in to assist Mr Holmes to maintain this sequence of events when Mr Holmes was teaching. This was done through cooperation between the teachers. For example, once in stage 3 when Mr Holmes did not follow the sequence of events as laid out in stage 2, Mr Wise stepped in and suggested a correction to the sequence at just the right time. Mr Holmes accepted the correction and made the change to the planned sequence of events to bring it back to the order shown in Figure 1. This example is shown in excerpt 4.
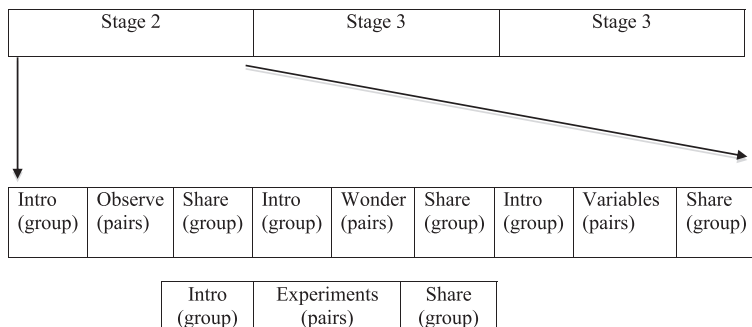

Figure 1. Organisation of scaffolded scientific inquiry activities in stage 2.

Excerpt 4

01	Mr Holmes	So what are some things that we might (.) wonder about in terms of our observations (.) with these um variables which is a word for uh the things that we can <u>change</u> (.) so what can I change about this ramp so Mr Wise has taped the ramp here what's something we could change about that (*facing students with line of gaze towards them*)
02	Mr Wise	° We should collect some observations first °
03	Mr Holmes	First↑ (*turning away from students towards speaker*)
04	Mr Wise	Yeah
05	Mr Holmes	>°Okay okay I'll just take one of these°< (*turning back to the students* and *pointing to a student who has her hand raised*) Yep
06	A	Um (.) you can put it upside down the other way
07	Mr Holmes	Alright (.) exactly so what we could do is (.) we'll set it up, we'll we'll <u>obser:ve</u> see what <u>happens</u> (.) with the ramp and the car and eh go from there (*turning away from students towards speaker*) > so should we just let em loose for the first part[†] <

The talk in excerpt 4 begins with a query (turn 1) made to the class regarding variables. That this was a query is indicated by the reply, which did not come until turn 6, when a student responded by suggesting a variable that could be changed. Turn 2, spoken in a quiet voice and indicating that observations should come first, was treated as an interruption by turn 3, as indicated by the physical turning away from the class and the repetition that indicated the shift in focus to the speaker of turn 2. Turn 2 was also a correction to an error in the sequence, as indicated by the repair in turn 7 that denoted a new sequence of events where observations came first. This interruption and correction maintained the organisation of events (Figure 1) laid down in stage 2, and was a joint effort between Mr Wise and Mr Holmes where Mr Wise offered the interruption and correction, and Mr Holmes accepted it and made the correction.

Interacting to create I-R-(A-R-) (Q-R-)(A- …) discourse chains

Examination of discourse forms during sharing periods in stage 2 (when Mr Wise was leading the class with Mr Holmes assisting) indicates the presence of the I-R-(A-R-) (Q-R-)(A- …) discourse chains. In stage 3, when Mr Holmes was leading and Mr Wise assisting we saw that Mr Holmes had acquired the habit of acknowledgement rather than evaluative turns in the third position. However, Mr Wise often stepped in to add the clarification questions that extended the I-R-A chain. An example is shown in excerpt 5.

Excerpt 5

		Turn	Speaker	Transcript
	I	01	Mr Holmes	[So what did you <u>change</u>
	R	02	Emily	I changed metal↑ I put metal on there↑ <so then> we would <so then> I would see how fast it goes↑
→	**A**	03	Mr Holmes	Yeah
	R	04	Emily	=And Brian had two cars↑
→	**A**	05	Mr Holmes	Yeah
	R	06	Emily	=And I (.) and then and (.) and one of them goes faster and [Brian
→	**CQ**	07	Mr Wise	[So let Brian talk about his, you talk about yours so you changed what it rolled on the bottom↑
	R	08	Emily	=Yeah
→	**CQ**	09	Mr Wise	And what <u>happened</u> to how fast it went
	R	10	Emily	Um it goes <u>faster</u>
→	**CQ**	11	Mr Wise	On the metal or on the normal floor↑
	R	12	Emily	O::n the metal
→	**A**	13	Mr Wise	Okay (nodding) that's a very interesting result↑ thank you

The discourse form in excerpt 5, like the example in excerpt 3, is of the I-R-(A-R-) (Q-R-) (A- …) type. In excerpt 5, there are three acknowledgement turns two (turns 3 and 5) that function as invitations for further elaborations (provided in turns 4 and 6 respectively), and one that ends the sequence (turn 13). There are three clarification question | response turn pairs {turn 7 | turn 8; turn 9 | turn 10; and turn 11 | turn 12}, with turns 7, 9 and 11 being treated as questions by the responses in turns 8, 10 and 12.

What is interesting about excerpt 5 is that Mr Wise takes over in turn 7 which de facto stops the on-going elaboration in turn 6 by means of overlapping talk and initiates elaboration of a specific aspect of Emily's experiment. Together with the further two clarification question | response turn pairs {turn 9 | turn 10; and turn 11 | turn 12}, this clarification probes for essential details of the story of Emily's experiment. This example can be seen as a model for Mr Holmes and the class and is a predecessor to the exchange between Mr Holmes and Laura and Jane in excerpt 3; when in turn 12 Mr Holmes posed a clarification question in the ongoing telling of the story of their experiment.

Discussion

This study was designed to provide answers to two main research questions pertaining to the change of discourse forms arising in an elementary science classroom taught by the regular classroom teacher co-teaching with a master teacher. The questions were 'How do teacher–student discourse forms change in a classroom that is part of the Steps to Inquiry co-teaching professional learning project?' and 'How do changing discourse forms arise in and from co-teaching?' Our study shows that over the course of the year when Mr Holmes' engaged in professional learning through co-teaching with Mr Wise, there was a pronounced shift away from teacher-dominated discourse forms towards use of the more student-centred discourse form and co-teaching with Mr Wise supported this change in a number of ways. In the first section of the discussion the discourse forms themselves will be discussed in relation to the literature. In the second section, the ways co-teaching supported the shift in discourse forms will be discussed.

Shifting to the student-centered discourse form

Predominant discourse forms 'Before'
Prior to the arrival of Mr Wise, Mr Holmes and his students mostly produced prompt-chorus (teacher–students) and initiate-respond-evaluate (teacher–student–teacher) routines. The prompt-chorus form attributes to the teacher the authority over the content (e.g. Mortimer & Scott, 2003): students only speak when prompted, and their speaking when prompted reproduces the teacher control over the discourse content. Whereas this discourse pattern clearly is the result of a joint effort, it provides the students with little opportunity to articulate content in their own words. That is, it limits students' opportunities to appropriate language and make it their own, which occurs when they speak a language and thus populate it with their own intention and accent (Bakhtin, 1981). The second interactional routine, initiate-respond-evaluate is well recognised in the literature (Mehan, 1979) and is a well-known example of a teacher-dominated discourse form (Mortimer & Scott, 2003). Affirming previous studies (e.g. Lemke, 1990; Mehan, 1979), our investigation shows that student turns never consisted of more than

one or two words. When the teacher and students produced this discursive form, the amount of student contribution to the talk was very limited.

Predominant discourse form 'After'

In contrast to the teacher-dominated forms, the initiate-respond-acknowledge (I-R-A) routine offered ample opportunities for students' voices to be heard. The I-R-A discourse form was most often found in lengthy interaction chains created by the addition of acknowledgement turns that were receipt tokens (e.g. Jefferson, 1984) or invitations for further elaboration, indicating to the speaker, to continue; and clarification questions that probed students for further responses about specific issues. These interaction chains had the form I-R-(A-R-) (Q-R-)(A- …) where Q is a clarification question. These interaction chains constituted the 'machinery' that produced the telling of the stories about activities. It is quite clear that the stories cannot be attributed to the students alone, for they were the results of the specific turn-taking routine with the teacher.

Similar interaction chains (I-R-F-R-F-) have been reported in the literature during dialogic teaching (e.g. Mortimer & Scott, 2003). These chains include feedback turns from the teacher and further responses from students. It is within these interaction chains that dialogic teaching and learning take place (e.g. Alexander, 2010). Although the feedback turns may be absent in the I-R-(A-R-) (Q-R-)(A- …) interaction chains, both I-R-(A-R-) (Q-R-) (A- …) and I-R-F-R-F-, introduce new information that elaborates upon or explains what has come before. The forms differ in the positioning of the student and teacher (Greeno, 2015). In I-R-F-R-F- chains the further information is coming from the teacher who has the third turn (F) and subsequent alternating turns (F), while in I-R-(A-R-) (Q-R-)(A- …) the further information is coming through student turns (R), that follow teacher clarification questions (Q). In I-R-(A-R-) (Q-R-)(A- …) it is the student who is the one who is positioned to contribute the additional information.

The I-R-(A-R-) (Q-R-)(A- …) chains occurred in particular situations (Rees & Roth, 2017). The situations were the whole group sharing periods that followed each of the small-group hands-on activities in the students' scientific inquiries, guided by the Steps to Inquiry framework (Figure 1). Frequent whole group sharing periods provide an ideal context for students to share their ideas, supported by the teacher (Harlen, 2018) through dialogic teaching (Alexander, 2010), where students develop their thinking and learning.

Such frequent sharing opportunities provide a more robust inquiry learning environment than the more common situation where students share only at the end of their investigations (Bjønness & Kolstø, 2015). Future work aims to investigate how the sharing periods could also be a site for students to develop their understanding of the processes of science and the nature of science (Abd-El-Khalick, 2012), through reflection and dialogic teaching.

In the next section, the ways that co-teaching supported the shift to the dialogic discourse form will be discussed.

The ways co-teaching supported the shift in discourse forms

Previous research indicates that in co-teaching for professional learning, teachers plan together and they codevelop resources, which they then use in the classroom for the benefit of student learning (Murphy & Beggs, 2005). In addition, through co-teaching together teachers learn from each other through tacit means: they pick up on each

other's styles and habits often without realising they are doing so (Roth & Tobin, 2002; Tobin, 2006). Teachers also learn from each other when they directly step in and out of the lead role, often seamlessly from the point of view of the class (Roth, Tobin, Carambo, & Dalland, 2005). They indicate to each other and make room for each other to take over. During co-teaching the teachers' focus is the learning of the students and together they contribute to it (Murphy & Beggs, 2010; Roth & Tobin, 2002). In this study, where the focus is on the professional learning of Mr Holmes, these forms of learning were evident. The next sections discuss each in turn.

Teachers learning through the use and creation of resources

Mr Wise and Mr Holmes co-planned their units using the Steps to Inquiry framework. The organisation of events evident in the classroom, that included the frequent sharing periods from which the I-R-A form emerged, followed the steps laid out in this framework. These steps were indicated on the 'Steps to Inquiry' set of planning posters that the teachers had posted on the wall. The steps included making observations, developing wonderings, brainstorming variables; choosing variables; phrasing a testable question; and conducting an experiment to find an answer. The posters had blank spaces that were places for the teacher (or students) to attach sticky notes (Supplementary material). On these sticky notes the teachers wrote the students' observations, wonderings, ideas for variables. The sticky notes were attached in particular spaces on the posters. These sticky notes were then moved from poster to poster, taking the class through the logic of the process of experimentation, and finally the findings from the experiments were displayed. Thus, the sticky notes and the posters were important resources that the teachers developed and used in their collective activity that led to opportunities for learning (for students and teachers). The writing of the students' ideas and findings on the sticky notes and the posting of the sticky notes on the poster, were an integral part of the I-R-A exchanges. There are indications that inscriptions, whether unchanged or transformed, provide for coherence across changing science teaching contexts (Roth & Friesen, 2013). Further research thus should focus on the precise ways that the sticky note and poster resources contributed to these exchanges.

Since the Steps to Inquiry framework was a key resource in helping the teachers and the class maintain the organisation of events, including those sharing periods, it was a key ingredient in the change in dialogue forms in Mr. Holmes classroom. The Steps to Inquiry framework was designed to support the shift to student-centred scientific inquiry through a grass-roots approach by a group of resource teachers (Pardo & Parker, 2010). Mr Wise and Mr Holmes made this framework their own through their co-planning and teaching together. It is thus important to focus research on resources that are effective for teachers, in order to develop theory on the effective design for teacher resources (Keys & Bryan, 2001). The Steps to Inquiry framework warrants further research in this regard.

Teachers learning by tacit means

In learning through tacit means during co-teaching, the less experienced teacher comes to know through working alongside a more experienced peer. The more experienced teacher teaches how to act in the situation without having to explain how (Winch, Oancea, & Orchard, 2015). Tacit learning occurs when the teachers work closely together by

participating together in their collective praxis (Roth et al., 2004). In this study, the teacher with less experience, Mr Holmes, appropriated ways of teaching from the more experienced teacher, Mr Wise. In stage 2 of the co-teaching process Mr Wise (who was leading the class) demonstrated the way of organising events for the science inquiries, and the way of talking with students in the I-R-A discourse forms. In stage 2 Mr Holmes was assisting Mr Wise and by stage 3 Mr Holmes had picked up on Mr Wise' ways to a certain extent.

Teachers learning by stepping in and out of the lead role

Prior studies have shown that during co-teaching, 'the teachers teach together with one or the other stepping forward to assume more central roles and then stepping back to augment the teaching of the other in ways that have the potential to improve the students' learning' (Roth et al., 2004, p. 677). In stage 3 there were many occasions where Mr Wise stepped forward to take over with Mr Holmes' permission. One kind of occasion when this occurred was when Mr Holmes had missed steps in the organisational sequence of events (see example in excerpt 4). If the situation had been left unchanged, the number of sharing periods would have been reduced which would have reduced the opportunities for the emergence of the I-R-A discourse form. Subsequently, in stage 4 Mr Holmes did maintain the sequence of events.

Another kind of occasion when Mr Wise stepped forward was during Mr Holmes interactions with students telling their stories of what they had done and what they thought. In these cases (see example in excerpt 5) he stepped forward and intervened to add clarification questions to the I-R-A discourse chains. Subsequently in stage 4 Mr Holmes included clarification questions (see example in excerpt 3) so that in his interactions with students during sharing periods, the full I-R-(A-R-) (Q-R-)(A- …) chain form was produced (see example in excerpt 3).

Conclusions

This study demonstrated that in the context of a co-teaching professional learning opportunity for student-centred scientific inquiry, using the *Steps to Inquiry* guiding framework, the discourse forms between teacher and students in Mr Holmes' class changed from a predominance of well-known prompt-chorus and initiate-response-evaluation (I-R-E) turn-taking routines towards a predominance of an initiate-response-acknowledge (I-R-(A-R-) (Q-R-)(A- …) routine that provides students with the opportunity to produce extended accounts of what they had done and what they were thinking. In the study, this (I-R-(A-R-) (Q-R-)(A- …) turn-taking routine emerged between teacher and students during whole group sharing periods that occurred after small group hands-on, student-centred scientific inquiry activities. The Steps to Inquiry guiding framework, in the hands of these teachers, supported the organisation of scientific inquiry events in the classroom to include these regular and frequent sharing periods.

Though co-teaching, the classroom teacher learned at the elbow of the master teacher to structure student-centred science inquiry activities, provide frequent and regular sharing periods for student-centred dialogue, and to 'act appropriately in the *here and now* of the unfolding conversation with the students' (Roth, Masciotra, et al., 1999, p. 772). Co-teaching with the master teacher provided the opportunity for the classroom teacher to develop a sense of what was right to do and say in a particular moment without requiring him to be fully self-aware of everything and all of the time.

Although it is not the focus of this study, we recognise that in co-teaching both teachers learn (Murphy, 2016; Roth & Tobin, 2002). Through the co-teaching experience, Mr Wise, as well as Mr Holmes, had opportunities to learn. For example, Mr Wise could learn specifically about teaching first-grade students, which was not his normal grade level.

This study adds evidence to support our knowledge of the value of co-teaching for profession learning, and it contributes to this knowledge by demonstrating how co-teaching can specifically support teachers shifting to student-centred modes of discourse, in the context of a parallel shift to student-centred scientific inquiry. Future work aims to extend this study to pre-service teacher contexts.

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