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Interchangeable Positions in Interaction Sequences in Science Classrooms

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Abstract

Triadic dialogue, the Initiation, Response, Evaluation sequence typical of teacher /student interactions in classrooms, has long been identified as a barrier to students' access to learning, including science learning. A large body of research on the subject has over the years led to projects and policies aimed at increasing opportunities for students to learn through interactive dialogue in classrooms. However, the triadic dialogue pattern continues to dominate, even when teachers intend changing this. Prior quantitative research on the subject has focused on identifying independent variables such as style of teacher questioning that have an impact, while qualitative researchers have worked to interpret the use of dialogue within the whole context of work in the classroom. A recent paper offers an alternative way to view the triadic dialogue pattern and its origin; the triadic dialogue pattern is an irreducible social phenomenon that arises in a particular situation regardless of the identity of the players who inhabit the roles in the turn-taking sequence (Roth & Gardner, 2012). According to this perspective, alternative patterns of dialogue would exist which are alternative irreducible social phenomena that arise in association with different situations. The aim of this paper is to examine as precisely as possible, the characteristics of dialogue patterns in a seventh-eighth grade classroom during science inquiry, and the precise situations from which these dialogue patterns emerge, regardless of the staffing (teacher or students) in the turn-taking sequence. Three different patterns were identified each predominating in a particular situation. This fine-grained analysis could offer valuable insights into ways to support teachers working to alter the kinds of dialogue patterns that arise in their classrooms.

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Introduction

Many classrooms still are characterized by the expositions of subject-matter-related truths that students are to repeat in (high-stakes) examinations (e.g. Hurst, 2013); presentations are monologic, in the sense that their purpose is to expound pre-established truths (Bakhtin, 1981). That is, even when lecture-type presentations involve exchanges with students, they remain as monologic as the late-Socratic "dialogues." A shift to more participatory dialogic forms of teaching | learning, therefore, may be made difficult by the fact that this requires the possibility to arrive at truths that were not previously established (Bakhtin, 1984). In a dialogue, we may identify pairs of utterances, such as question/answer, agreement/disagreement, or affirmation/supplementation. But these relationships are not to be found in language—"relations between question and answer, assertion and objection, assertion and agreement … are impossible among units of language (words and sentences), either in the system of language … or within the utterance" (Bakhtin, 1986, p. 72). Such relations are not linguistic at all; they are social. The Socratic dialogues show how the parts of the conversation—e.g., question and answer—are related to the role of participants. Thus, Socrates tends to ask questions, some respondent, which may be a learner, gives the answer, and Socrates evaluates in one form or another. Here, then, particular grammatical forms come to be associated with social, teacher–student distinctions.

In the literature, one of the best well-known verbal exchange patterns is known as IRE, short for initiation, reply, and evaluation; the three slots of the pattern are filled by the teacher (who asks a question), a student (who responds), and the teacher (who evaluates), respectively (Lemke, 1990; Mehan, 1979). However, one more recent study suggests that the phenomenon is much more widespread and can be found, for example, in nature centers, where the IRE phenomenon is staffed by nature guide, visitor, and nature guide, respectively (Roth & Gardner, 2012). Moreover, the pattern has been identified in impromptu tutoring sessions on reading science graphs (Roth & Middleton, 2006) where the first and third slots are staffed by person(s) *who are in the know* (an undergraduate student in physics) and others (physics professors) staff the middle slot. That is, the IRE pattern appears to be a cultural phenomenon that reproduces itself in various places, staffed by very different people sometimes taking an unexpected place. Might it be that even in schools, the staffing does not involve the teacher-student-teacher sequence? This study was designed to investigate the relationship between grammatical forms, institutional position (teacher, student), and topic-specific situations in the context of classrooms where teachers aspire to more dialogical (in the Bakhtinian sense) forms of verbal exchange.

Background

Much has been written about unequal access to science learning in classrooms, and one feature that can make a difference is the style of classroom talk (e.g. Lemke, 1990). The way that teacher and student talk unfolds has a bearing upon students' decisions about whether to engage in learning science, what they might learn, how empowered they might feel in relation to science, and how likely they are to identify themselves as science learners (Hanrahan, 2005). Studies of discourse patterns in science classrooms can help researchers understand possible mechanisms that impose barriers to access and mechanisms that can draw students in. Such studies indicate that the triadic IRE pattern predominates in classroom talk (Lemke, 1990). Take Fragment 1 from a seventh-/eighth-grade science classroom.

Fragment 1

I>	01	P1:	What did you guys put in first? The water–
R>	02	P2:	The rocks.
I,E>	03	P1:	The blue rocks? Or the big rocks?=
E,R>	04	P3:	=>You're s'posed to< put the filter in fir::st.

In this fragment, there is an initiation, which includes a query and the offer of an item ("the water") that might be part of a reply (turn 01). There is what we can hear as a reply (turn 02), which then becomes the subject of the initiation of a repair seeking a specification of the preceding reply ("the rocks") in terms of some blue or big rocks (turn 03). Turn 03 does not only seek further specification of the answer, that is, initiate a repair, but also it is a form of evaluation. This is so because in seeking to find out whether the respondent meant the blue or the big rocks, turn 03 also evaluated the reply as insufficient. Turn 03 also shows that the person is in the know about the situation that the participants are talking about. Turn 04 can be heard both as an evaluation of turn 02: not the rocks but the filter should have been placed first. Turn 04 therefore also constitutes the norm against which the reply (turn 02) and the actions to which it corresponds are evaluated.

This ordered form of turn-taking in classroom talk is often seen as a barrier that teachers present for many students because it can require students to perform according to a certain conception of science, taking away the possibility for them to propose alternative explanations or interpretations, take initiative, ask questions, or direct the conversation (Lemke, 1990; Bleicher, Tobin & McRobbie, 2003; van Eijck & Roth, 2011). However, what is interesting about the preceding example (Fragment 1) of triadic turn-taking is that it did not occur between a teacher and her students: all four participants in the talk are students. In fact, the sequence occurred while the teacher was busy helping other students in a different part of the classroom. As suggested by Roth & Gardner (2012), regardless of the identity of the players who take the slots in the turn-taking routine, a similar dialogue pattern emerges when a person in the know is asking the questions. The triadic dialogue pattern is a social phenomenon that arises in particular situations, regardless of the staffing. This is important in the context of science classrooms because it suggests that rather than teachers intentionally imposing particular dialogue patterns, the patterns may be arising out of the particular situations in the classroom, regardless of the staffing of the dialogue patterns. If this is the case it may be that changing dialogue patterns depends more on changing situations than it does on changing teachers' intentions.

Since the 1970s and the advent of easy access to recording equipment, there has been an interest in the study of classroom talk. Numerous studies pointed out the prevalence in teacher/student discourse of a pattern termed IRF, short for *I*nitiate, *R*espond, *F*eedback (Sinclair & Coulthard, 1975) or IRE, short for *I*nitiate, *R*espond, *E*valuate (Mehan, 1979). Over the decades since then, many researchers have investigated and agreed upon the barriers that this pattern of classroom talk can present (Cazden, 1988; Heath, 1983; Mercer & Dawes, 2014). It limits students to only speaking 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 themselves from deciding when to speak; and it inhibits students from speaking to each other directly (Cazden, 1988). Although there are studies suggesting some positive value of the IRE pattern in the reproduction of cultural forms (Roth & Radford, 2010), the pattern tends to be considered as a barrier to learning. It continues dominating classroom talk today, even though the desire for alternatives is often expressed (Hardman, Smith & Wall, 2003). Projects designed to encourage alternatives have of course made good progress. For example, the Fostering Learning Communities project (Brown, 1992) has proven to support such opportunities for extended interactive and equitable exchanges between teachers and students that are effective learning opportunities (Engle & Conant, 2002). Even though the body of literature on classroom talk has driving policy to implement change (Mercer & Dawes, 2014), for many teachers, creating such alternatives for classroom talk continues to prove difficult even when they have the intention to make such changes (Lyle, 2008).

In the literature, teachers themselves often are portrayed as the barrier (Sedova, Sedlacek & Svaricek, 2016). It has been suggested that teachers sometimes purposefully hold on to the triadic

dialogue mode of discourse because it places them in a position of control (Hanrahan, 2005). More recently, several authors have proposed that triadic dialogue may be continuing because it serves some useful purposes in science education (e.g. Scott, Mortimer & Aguiar, 2006; Wells & Arauz, 2006). One recent study suggests that triadic dialogue is an irreducible cultural phenomenon that emerges in certain situations regardless of the players involved (Roth & Gardner, 2012a).

> From the perspective of irreducibly social phenomena, the IRE sequence transcends the teacher's intentions; the sequence is a social phenomenon staffed in this case by Mrs. Turner. It is staffed differently in other situations, such as in the driver's license bureau or in our university's annual fire-training certification, where the computer initiates, the want-to-be-licensed individual responds, and the computer evaluates. (Roth & Gardner, 2012, p. 340.)

It is easy to see in the quotation that the IRE pattern is arising in situations where someone who is in the know is testing another person. Alternative dialogue patterns can also be seen as irreducible social phenomena that arise in particular situations. Other discourse patterns have been identified, such as the initiate-clarify-reply and initiate-reply-clarify-reply sequences found in natural pedagogical conversations between a technician and high school students during a science internship (Hsu, Roth & Mazumder, 2009). The patterns arose in situations where one participant, in this case the laboratory technician, was demonstrating how to use a machine or perform a procedure that the high school student will practice. It is easy to see how such patterns might arise and to anticipate situations where they are staffed differently, such a when one family member is teaching another how to use the lawn mower or how to reproduce a recipe. This way of viewing dialogue patters as irreducible social phenomena that arise in particular situations regardless of the staffing of those situations could be helpful in our efforts to developing understanding of why particular dialogue patterns persist and others are elusive in classrooms. It may help explain why the best intentions of teachers can be foiled.

Methods

The aim of the study was to investigate (a) patterns of talk in the classroom, (b) the players involved in the turn-taking sequences, and (c) the precise situations from which these patterns arise.

Context

The study took place in a seventh-/eighth-grade classroom during a science inquiry unit on water filtration. The class had already participated for one year in the Steps to Inquiry project. During that year, the teacher, together with several peers, engaged in a series of professional development workshops designed to change their approach to science teaching. Following the workshop, the teacher had been a member of a community of teacher-learners, which was provided with release time to develop curriculum.

The Steps to Inquiry project was designed to support teachers and students moving toward student-centered science inquiry. In the project teachers and students learn to conduct student-centered science inquiry through the use of the Steps to Inquiry framework that a team of teachers had developed (Pardo & Parker, 2010). The framework assists teachers in relinquishing some responsibility for science investigations to students. The steps follow the levels of inquiry described in the literature (Bell, Smetana, & Binns, 2005). The framework provides materials to teachers including a series of interactive posters and graphic organizers that teachers and students use to scaffold the framing of student-centered science investigations. Using the interactive posters and graphic organizers, teacher and students work together to collect ideas and questions, support the phrasing of testable questions for science inquiry,

identifying variables, designing procedures, and conducting independent, small-group science investigations (cf. Buttemer, 2006; Goldsworthy & Feasy, 1997).

Participants

Participants include the teacher (Ms. A.), a guest expert (Mr. G.), the researcher (CR), and students from the seventh-/eighth-grade classroom.[1]

Teacher. At the time of the study, Ms. A, the teacher had eleven years teaching experience. She had completed a non-science major prior to entering an elementary teacher education program. She had completed professional development workshops with the Steps to Inquiry framework during the academic year preceding the study; and throughout the year attended monthly meetings with the teacher group.

Guest expert. Mr. G. was the science resource teacher for the school district. He had a Master's degree in science and over ten years experience as a secondary school science teacher. Mr. G. was involved in the creation of the course materials and was one of the initiators and leaders of the Steps to Inquiry project.

Researcher. The principal researcher (CR) attended the professional development workshops with the teacher. She visited the classroom and attended several monthly meetings with the teacher group throughout the academic year in which the data were collected. In addition she has visited other classrooms that are part of the Steps to Inquiry project and introduced the associated materials in her university courses for pre-services teachers.

Students. The school was located in a low socioeconomic neighborhood in a mid-sized city in Canada. In the participating class, 12 students were in seventh grade (6 boys and 6 girls) and 14 students were in eighth grade (8 boys and 6 girls). The class was highly diverse in that (a) visible minorities included 3 African American students, 1 East Indian student, 3 First Nations students, 1 Latino student, and 1 Asian student and (b) special needs students included 8 students with individual education plans and 1 student with a behavioral safety plan. There were also 2 English language learners (defined as students who are learning English at the same time as they are learning the curriculum, Ontario Ministry of Education n.d.)).

Curriculum Unit

The unit on water filtration was part of a larger unit on water systems in the Grade 8 Ontario Curriculum for Science and Technology. The central idea of the water filtration unit is captured in the statement: "Water is an important resource that needs to be managed sustainably."

To construct the pop bottle water filter, a 2L pop bottle was cut in half. The top part was inverted and placed in a ring clamp on a retort stand. A coffee filter, sand, aquarium stones and larger stones were used to construct the water filter. Pond water was filtered through the pop-bottle water filter. A beaker was placed beneath to collect the filtered water sample.

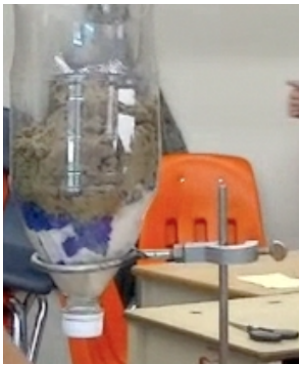

Figure 1. The pop bottle water filter

[1] The study followed the standard research ethics protocols of the country: Data were collected following research ethics approval and signing of consent forms by the teacher, visiting expert, students and guardians.

The Steps to Inquiry materials (Youth Science Canada, n.d.) were used to guide the teacher and students through the process of collecting their observations, deciding on variables to change, and phrasing a testable question (Rees, Pardo & Parker, 2013). Table 1 is an event map of the water filtration science inquiry.

Table 1
Event Map of the Water Filtration Unit

Day	Event Map	Time (min)
1	Teacher demonstration of water filter construction (whole class)	7
	Student recollection of sequence of construction (whole class)	11
	Student replication to construct 'control' water filters (small groups)	14
	Ranking of filtered water samples by eye (whole class)	21
2	Introduction to turbidity measurement (mixed)	27
	Turbidity measurement (small groups)	10
	Discussion of sources of error (whole class)	8
	Identification of variables to change (whole class)	10
	Making predictions of effect of changing one variable (small groups)	19
3	Conducting experiments to determine effect of changing one variable (small groups)	32
	Turbidity measurement of water samples (small groups)	26
	Discussion of results (whole class)	9
	Recording and interpreting results (small groups)	9
	14. Real filtration system discussion (whole class)	7
	Total	210

In the first part of the inquiry, students observed a teacher demonstration on how to construct a pop bottle water filter. They reproduced the teacher's demonstration to construct their own water filters. They then designed an experiment to test the effect of changing one variable of the pop bottle water filter on the filtered water. Students framed a testable question, decided on a dependent variable to measure, an independent variable to change and control variables to keep the same. They conducted their experiment, collected relevant data, and interpreted the results obtained.

Data

One video camera was used to record video and audio recordings throughout the water filtration unit. These recordings provide the data for detailed conversation analysis in this study. All recordings were transcribed. The total time of recordings was 210 minutes.

Analyses

This study is concerned with patterns emerging from sequentially ordered turn-taking during science classroom talk. Conversation analysis is the method of choice in this study because it focuses on the structure and dynamics of conversational patterns that emerge in contexts of action and interaction (Sacks, Schegloff, & Jefferson, 1974). Conversation analysis follows how agents in a conversation take up what has been done and said on the part of others. This approach reveals participants' take-up of what has been said reflecting the analyst's inferences. To hear the participants in the way they hear each other requires the analysts to be as competent as participants in the topic and cultural practices.

The first step in the analysis involved viewing and listening to video recordings, and examining corresponding transcripts to identify fragments that contained patterns of particular interest to the study (Roth & Hsu, 2010, 2012). The identity of the persons staffing positions in the patterns were removed from the transcripts so that the focus was on the pattern and the situation where the pattern emerged. The term Person 1 (P1) and Person 2 (P2) were used. In the analysis step, we made use of interaction analysis, a form of analysis where the researchers meet with interested colleagues and graduate students to analyze the data (Jordan & Henderson, 1995). The "data owner" plays the video until someone requests stopping the play for the purpose of analyzing the sequence seen. All those present hold each other accountable to the data, that is, the analysts must not speculate about the contents of peoples' minds but formulate claims that can be supported in the data. The second step involved examination of these fragments and detailed transcription (Atkinson & Heritage, 1984; Sacks et al., 1974), including annotation of the following (see Appendix): overlapping speech (and duration of overlap), pause (including duration), changes of intonation and speech volume, and any pertinent non-verbal communicative features (Hsu, Roth & Mazumder, 2009). In this analysis, the function of a turn is determined from the turn pair. Thus, for example, it is not our interpretation that something is a question, instead, a turn (statement) is a question because the next turn treats is as such. The next turn indeed constitutes both the nature of itself and the nature of the preceding turn.

Findings

Relationship between Situations, Dialogue Patterns, and their Staffing

This study was designed to investigate dialogue patterns in particular situations in a seventh-/eight-grade classroom and the staffing of these patterns. The specific context of the inquiry is a seventh-/eighth grade classroom during a water-filtration science inquiry. In the first subsection, we introduce three particular situations and the discourse patterns that arise in these situations; in the second subsection, we focus on the staffing of the discourse patterns.

Dialogue Patterns and Situations

The three situations are: Situation 1 where observations, recollections or ideas were being collected; Situation 2 where new equipment or skills were being demonstrated and practiced; and Situation 3 where problems were being discussed and solved. Three pattern types identified from the literature were found. These patterns, evident as basic units, were often repeated in chains. In this section we describe the patterns and their distribution across the three different situations.

Dialogue patterns. The three dialogue patterns types are: Type A patterns (IRE / IRA); type B patterns (ICR / IRCR); and type C patterns (I^nIR / IR^n-IR). These dialogue pattern types are further described below.

Type A patterns (IRE / IRA). The first was the IRE (Initiate, Respond, Evaluate) pattern, also know as triadic dialogue, reported in the literature to be common in classrooms, including science classrooms (Lemke, 1990), where the third evaluative turn in the pattern indicates that the answer to the question posed in the Initiate turn was already known. A variant of this pattern that we called IRA, was also evident. In IRA (Initiate, Respond, Acknowledge), instead of the third turn being an evaluative turn it indicated an acknowledgement.

Type B patterns (ICR/IRCR). The second pattern type was the ICR / IRCR pattern (Initiate, Clarification, Respond; or Initiate, Respond, Clarification, Respond), reported in the literature to occur during natural pedagogical conversations, in a study that analyzed conversations during an internship for high school students' in a professional science laboratory (Hsu et al., 2009). In the earlier study, this pattern had emerged during conversations between the laboratory technician and the high school students.

Type C patterns (I^nIR / IR^n-IR). The third pattern type I^nIR / IR^n-IR (Initiate turns originating from different speakers often overlapping, followed by an Initiate turn that brings the contributions together, followed by a Response turn of agreement; or an Initiate turn followed by Response turns originating from different speakers and often overlapping followed by an Initiate turn that brings the contributions together, followed by a Response turn of agreement). This type of pattern has not been reported in the literature but can be seen in transcripts reported in the literature during occasions such as cumulative talk (Mercer, 2000). Table 2 indicates the relative frequency of these pattern types in the three different situation types observed.

Table 2
Frequency of Discourse Patterns in Particular Situations

Pattern	Situation Gathering observations, recollections and ideas (N = 182 turns)	Situation 2 Demonstration/Practice (N = 174 turns)	Situation 3 Problem Solving (66 turns)
Type A patterns IRE / IRA (triadic talk)	152 (84%)	28 (16%)	26 (40%)
Type B patterns ICR / IRCR (natural pedagogical talk)	25 (14%)	123 (71%)	
Type C patterns I^nIR /IR^nIR (distributed talk)	5 (2%)	23 (13%)	40 (60%)

Relationship between dialogue patterns and situations. As Table 2 shows, Type A patterns predominate in situation type 1, when students made observations, recollected, and produced ideas; Type B patterns predominate in situation type 2 when there is demonstration / practice of a new machine or a new skill; and Type C patterns predominate in situation type 3 when there is problem-solving. Further details of the dialogue patterns found in each situation are presented below.

Gathering observations, recollections and ideas (Situation 1). Type A patterns (the IRE/IRA patterns) were predominant in the classroom and they were found primarily in Situation 1 where observations, recollections and ideas were being gathered. IRE patterns ended in an evaluative turn while IRA patterns ended with a turn of acknowledgment. IRE patterns predominated in situation 1a when recollections of past events were being collected. For example, when the teacher was asking the students to recall what she had done and the exact sequence in her demonstration of how to build a water filter (see example in Fragment 2 below). In this situation (1a) out of 18 iterations of type A patterns, 15 ended in an evaluative turn (IRE). This pattern was also observed between students when recollections of past events were being collected (Fragment 1 in the Background section). In situation 1a there was a "correct" answer regarding what came next in the sequence of events that were being recalled.

In contrast, IRA patterns predominated when ideas were being collected (Situation 1b) and there was not a "correct" answer. For example, when the teacher was collecting the students responses to the question "What is one thing you could change about the water filter." In this situation (Type 1b) 8 out of 11 iterations of type A patterns did not include an evaluative turn (IRA). The teacher repeated the idea and wrote the idea on a sticky note, and attached it to the poster. The other three iterations ended with repeating the idea and the addition of a word that could have been evaluative (okay) (IRE). In situation Type 1b, the teacher was accepting all ideas.

Type A patterns were not the only pattern types found in Situation 1, type B patterns (ICR / IRCR patterns) were found when students were making observations of what the teacher was doing during a demonstration, and taking notes. In this situation type 1c, the teacher initiated by asking "Do you have any questions?" Students asked clarification questions such as "What is that called?" or "How much water did you put in?" The teacher responded by answering the student's question and the students wrote the responses in their notes. As well, in situation type 1 there was one example (Situation 1d) of the type C patterns (I^nR /IR^nIR patterns). It occurred when a student initiated by interrupting the teacher who was at the time writing down student recollections of a past activity. The student pointed out a problem of missing information in what the teacher had written. Several other students interrupted and contributed and through the joint work of different contributors a decision was made about the substance of the missing information, the teacher repeated the information and added this to her sticky note.

Situation 2: Demonstration/practice. Type B patterns (ICR / IRCR patterns) were less frequent overall but they predominated (71%) in the situation when new equipment or skills were demonstrated and practiced, for example, when a guest expert was showing the students how to use a turbidity meter to measure the turbidity of their water samples and the students were following through on measuring. The guest expert explained to the students how to set up the samples and place them in the turbidity meter, students asked clarification questions, and the guest expert responded. Fragment 3 below is an example of this type of pattern that occurred when the guest expert was explaining how to make a dilution; and Fragment 4 below is an example that occurred when students were working together to make dilutions. As well as Type B patterns, Type A patterns (the IRE/IRA patterns) were found in situation type 2 but at a lower frequency (16%). Type A patterns were found when the teacher asked students to recall their knowledge of past events; for example, when she asked them to recall what came next in the

experimental procedure. In Situation 2 there were also several instances (13%) of type C patterns (I^nIR /IR^nIR patterns). These were seen when a problem arose. For example, when the guest expert and teacher realized the samples were too cloudy to get a reading on the turbidity meter (see Fragment 5 below). Through several contributions from different speakers, and the joining of contributions from several speakers, a plan emerged to dilute the samples, a participant stated the course of action, and the participants agreed upon it (*R*).

Situation 3: Collaborative problem solving. Type C patterns (I^nIR /IR^nIR patterns) predominated when the class was collectively working to solve a problem (60%). For example, when the teacher asked the class how they might rank the water samples a student suggested they rank them according to color, a second student interrupted to point out a problem, which was that the volume of water in the containers were different in some cases and this could affect the color (see Fragment 6 below). Through the joining of different contributions from different speakers a solution was proposed to make all samples the same volume that was accepted by the group. As already indicated, Type C patterns were also found when problems arose unintentionally such as when the teacher and guest discovered that the samples were too cloudy to read with the turbidity meter. In situation type 3, Type A patterns were also found when the teacher was asking the class to supply ideas of what they could measure or observe (dependent variable) about the water to make their decision about the impact of the altered variable (independent variable).

Staffing of the Discourse Patterns: Players in the Turn-Taking Sequences

In the literature, the existence of particular dialogue patterns in classrooms is usually seen as a reflection of the intention of teachers. In the case of the IRE dialogue pattern for example, teachers are sometimes portrayed as hanging on to the IRE pattern because it allows them to maintain a position of authority (Hanrahan, 2005). Analyses such as Hanrahan's, however, could be problematic because they fail to take into account a power–knowledge dialectic (e.g. Foucault, 1975), and exactly who is in the know always is worked out situationally such that the tables are turned when an undergraduate student is treated as knowing more than his physics professors (Roth & Middleton, 2006). However, if dialogue patterns are cultural phenomena that arise from particular situations (Roth & Gardner, 2012), then their frequency in classrooms might be due to the frequency of those situation types, rather than being due to teachers' intentions. The data in the previous section indicate that particular dialogue patterns types predominate in particular situations. In this section of the paper, we show that these three dialogue pattern types, in their particular situations, can be staffed differently; the identity of the players at the posts in the turn-taking sequences does not depend upon their institutional position (teacher, student). For example, it is not always the institutional teacher who takes the first and third positions in the triadic dialogue (IRE) sequence.

Type A patterns (IRE/IRA). Analysis of the two dialogue fragments (Fragment 1, which opens this paper, and Fragment 2) indicates that they follow the same triadic dialogue pattern even though different players (teacher or students) inhabit the roles in the turn taking sequence. The example in Fragment 1 that occurred between students has already been described. The example in Fragment 2 is more typical of IRE patterns in classrooms. P1 is the teacher and P2, P3, and P4 are students. The example occurred when the teacher was collecting recollections (situation 1b) of the sequence of steps she had taken in the construction of the water filter, something she had just completed demonstrating to the class.

Fragment 2

I>	01	P1	A::nd. then what did I do (.) Trent? (leaning over the desk, writing on a notepad)
R>	02	P2	Then you took the bottle you put the lid down first through the ring clamp=
E/I>	03	P1	=After I touched the retort stand ↓what did I have to do (stops writing sits up straight puts hand under chin and finger to lips)
R>	04	P2	Uh, you put it down on the desk
E/I>	05	P1	And then? (nodding and smiling P1 leans toward her notepad with her pen in her hand)
R>	06	P2	[You put the two liter (.)] put the lid down [(……..)]
E>	07	P1	[sits back up shaking head]
R>	08	P3	[U:m, she didn't]
R>	09	P4	[Put in the ring] clamp=
R	10	P2	=I just said that
E>	11	P1	I added a ring clamp (.) good (resumes writing on a note pad)

In Fragment 2, in the turn 1 | turn 2 query | reply turn pair, a query initiates and addresses the next step in the sequence of addition of elements in the building of the pop-bottle water filter. The reply in turn 2 is a description of an action taken. That the answer offered in turn 2 is evaluated as not satisfactory or correct is indicated in turn 3 by a halt in writing on the notepad and a prompting for a different answer. The prompt is to consider a step in the sequence of addition of elements that had to be done next. Turn 4, in response to the prompt in turn 3 describes a prior action taken. That writing on the notepad does not resume in turn 5 indicates an evaluative turn again, where the response in turn 4 is not judged as sufficient, and the query in turn 5 "And then" is a prompt for elaboration. Turn 6 in response to turn 5 is another proposal for what the next step was. That turn 6 is not taken as correct is indicated in turn 7 by the shaking of the head and by the shift to an upright body position, away from the leaning forward writing position. Turns 8, 9 and 10 are offered by three different speakers and are also responses to turn 5. That turn 9 is taken as the correct response and the next step in the sequence is indicated in the evaluative turn 11 that repeats turn 9—"added a ring clamp" and evaluates by saying "good" and by the resumption of the writing in the notepad.

In Fragments 1 and 2 there is a person or people at the initiating turns, who, as shown by his/her filling the third slot (staffing the first and third turns), already is in the position of knowing the answer. Regardless of the players that inhabit (staff) the roles in the turn-taking sequence, a similar pattern emerges.

Type B patterns (ICR/IRCR). Analysis of the two dialogue fragments (Fragment 3 and Fragment 4) indicates that they follow the ICR/IRCR pattern even though in each case different players (teacher or students) inhabit (staff) the roles in the turn taking sequence.

In our study, we first found the ICR pattern when an expert demonstrated a new skill and learners then practiced. An example of an ICR pattern (Fragment 3) from this situation is shared below. This fragment occurred when the person P1 staffing the initiate (I) position of the ICR sequence was demonstrating how to make a dilution of the water samples in preparation for measuring turbidity using the turbidity meter.

Fragment 3

I>	01	P1	You're going to take your sample and you're going to put one pipette in - into the beaker. So your sample of blue stuff goes in the beaker. Hang on one. Then you're gonna add 10 of the clear water (.) afterwards. Then you're gonna put one of the blue and ten of the clear.

C>	02	P2	How many times do you want us to do that?
R>	03	P1	Well let's see how much volume we get at the end of that. You need enough, you need enough to fill one of these.

Fragment 3 begins with an initiation (turn 01) where P1 is explaining and showing that to make a dilution of the water sample participants need to take one pipette-full of the sample and put it in the beaker and then add 10 pipettes full of clear water and then repeat. In turn 02, the clarification turn, P2 asks a clarification question regarding how many times they need to repeat that step. In turn 03, the response turn, P1 answers that they will need to see whether the final volume is enough to fill the vial that is used in the turbidity meter. In Fragment 3, like the technician in the Hsu et al. (2009) study, P1 is an expert (Mr. G.) who is visiting the class. P2 is a student. Further examples of this type of pattern were seen whenever the expert and the students were involved in similar demonstration-practice activities learning to conduct other science techniques, including learning to use the turbidity meter.

There were other times that this pattern type was seen when Mr. G. was not involved in the conversation. The initiate position was staffed by a person other than Mr. G. One such example of the IRCR pattern is provided in Fragment 4.

Fragment 4

I>	01	P1	Then do the finger squeeze
R>	02	P2	Okay
C>	03	P1	Same thing with water↑
R>	04	P3	(2) Same

Turn 01 initiates (I) with a direction "then do the finger squeeze" indicating the squeezing of the bulb of the pipette needed to expel the liquid into the beaker. The affirmative response "okay" follows in turn 2. Turn 03 is a clarification question whether the same thing (is done with water) that is answered in the affirmative response in turn 04 by the repeat of the word "same." In this example (Fragment 4) P1, P2, and P3 are all students. The students are working on their own in the practice phase following a demonstration by the guest expert of how to make dilutions. What is relevant to the argument in this paper is that the IRCR pattern is emerging in association with the situation of demonstration and practice, regardless of the players involved in staffing the positions.

Type C patterns (I^nIR/ IR^nIR). The distributed contributions pattern was seen in situation type 3, when the whole class was intentionally engaged in problem solving and also when a problem emerged that interrupted the course of a situation when other patterns where predominant.

The first example (Fragment 5), a pattern consisting of a series of distributed initiations followed by an initiation/response turn pair (I^nIR), occurred when a problem arose during the activity of turbidity measurement (Situation 2). The I^nIR pattern is seen in turns 9–14. The earlier turns that follow the ICR pattern are included to show the emergence of the problem to which the suggested solutions are addressed. The group is preparing their water filter samples from their pop-bottle water filters for turbidity measurement. The problem that is unfolding is that the turbidity of the samples is so high that the values are off the scale of the turbidity meter—all measurements of all samples are of greater turbidity than the maximum that the turbidity meter can measure.

Fragment 5

I>	01	P1	That seems to be (.) that's maxed out ↓ (.) so let's see what we get [let's try some more]
C>	02	P2	[Mine's maxed out now↑]
R>	03	P1	It's still (.) everything is maxed

In turn 1 the problem unfolds in the statement "that's maxed out" uttered during the reading of the value on the turbidity meter. This is followed by a query | reply pair in turn 2 | turn 3. The query in turn 2 is with regard to whether that individual's sample is maxed out and the reply in turn 3 indicates that everything is maxed.

The group continues to test the different water filter samples. Forty seconds later, in a query/reply turn pair (turn 4 | turn 5) an initiation in turn 4 is a suggested solution to the problem that has emerged. This suggested solution is to dilute the samples by the same amount.

Fragment 5 (continued)

I>	04	P1	Um (2) what if we diluted them all the same↓
R>	05	P2	Yeah we may have to (3) yes (.) we'll::: (2)
C>	06	P1	That wasn't my idea↓=
E>	07	P2	=It's a good idea=
	08	P1	=laughter
I>	09	P2	I would say we're probably going to have to dilute these by:::↑
I>	10	P1	=cos I thought pipettes we could fill them to:::
I>	11	P2	= five to one I'd go five to one (.) just to start off with↑
I>	12	P1	Do you want to do that↑ =
R>	13	P2	= yeah
R>	14	P1	okay
E>	15	P2	that's a good plan I think that's >what we're gonna have to do↓ <

The reply in turn 5 is an affirmative response to the suggestion in turn 4. Two seconds later in turn 06 | turn 07 the high quality of the idea is established followed by laughter in turn 8. The distributed pattern that we identify as (I^nIR) begins with a series of iterations in turns 9–11, distributed across individuals. These initiations are suggestions regarding the action to be taken in response to the problem. The first concerns the amount to dilute the sample by (turns 9 and 11) and turn 10 concerns the means by which to achieve the dilution (the use of pipettes). The series of iterations is followed by turn 12 which is an initiation query proposing a decision regarding the action that should be taken. Turn 13 is an affirmative response that is accepted in turn 14. The quality of the proposed plan is attested to in turn 15 and the proposition that this is the required course of action.

In this example (I^nIR), the persons staffing the positions are P2, the teacher and P1, the expert guest. The pair reach a final decision to use pipettes to measure and set up 5:1 dilutions to solve the problem of the samples beings too cloudy for the turbidity meter. This appears to be a collaborative decision where P1 and P2 each offer contributions that are a series of initiations that are brought together to form the planned course of action.

In the second example (Fragment 6) the distributed contributions pattern (this time IR^nIR) occurs in Situation 3 when the class is working together to solve a problem that has been presented, that of whether colour can be used as the characteristic to compared the filtered water samples. Turns 02–07 constitute the pattern IR^nIR.

Fragment 6

I>	01	P1:	=But some they have more in to make it look um: darker or lighter or something
R/I>	02	P2:	Okay (1) How do you mean darker and lighter
R>	03	P1:	Like – like like (2) ˚I don't [know˚(……..)]
R>	04	P3	[the more we're]
R>	05	P4:	=seeing different colour than the others
R>	06	P3:	= like more your seeing or something
I>	07	P2:	= Oh - okay so P3 is saying if this one has fifty mils and another one has two hundred mils (pause)
R>	08	P1:	=It might look different
R>	09	P2	= It might look different?
I>	10	P1	=We should all put them in the two hundred cup or fifty mils or like how much ever

The problem is addressed in the sequence of turn 1| turn 2. It relates to the fact that the samples were of different volumes and therefore could appear to be different colors because of that (rather than because of differences in cleanliness). The second member of the pair treats the opening statement as incomplete with respect to the degree of darkness or lightness. Turns 3, 4, 5 and 6 constitute replies to the query in turn 2 ("what do you mean darker or lighter") that is a query for clarification of the problem that unfolded in turn 1. Turn 3, after a pause, adds, "I don't know." Turns 4 is the beginning of a reply and turn 5, is an interjection followed immediately by turn 6. Both turn 5 and turn 6 contribute suggestions to help clarify the problem. Turn 5 concerns the difference in the color and turn 6 refers to the difference in the amount "the more you're seeing." In turn 7 these suggestions that were distributed across turns 4, 5 and 6 come together in the connection of the amount and the appearance using an example "if one has 50 milliliters and the other has 200 milliliters they might look different." The example is restating the problem that has unfolded in the conversation (turn 1), and clarifying it. In turn 8 the phrase "it might look different" is repeated and this is followed by an initiation that is a suggestion that is a plan of action to put the samples in the same size cup.

Fragment 6 continues through to final agreement of the group in turns 16–18.

Fragment 6 (continued)

R>	09	P4:	=But this like (.) that person has only a tiny bit not even two hundred or fifty: =
R>	10	P1:	=Yeah, but like-
I>	11	P2:	So what do we want to do? How do we want to make that a fair test then?
R>	12	P4:	make them all fifty mils
I>	13	P2:	So we want to make them all fifty mils?
R>	14	P4:	Yeah
I>	15	P1:	Who agrees?
I>	16	P2:	Does that sound (2) fair?
R>	17	P1:	Yeah=
R>	18	P3:	Yeah=
R>	19	P4:	Yeah=
E>	20	P2:	=Because then we're measuring the same thing, right?

Turn 9 is a response to the suggestion made in turn 8 that is the unfolding of another problem—the problem that some samples are too small, not even 200 or 50 milliliters "that person has only a tiny bit." Turn 10 acknowledges that a solution is needed in the statement "yeah but like" and turn 11 brings the question to the whole group about the course of action to be taken. Turn 11 also phrases the question

as being one of how to compare the samples through "a fair test." Turn 12 constitutes a reply to turn 11, in stating that they should all be made 50 milliliters. In turn 13 this potential solution is offered up to the whole group in response to turn 12. Turn 14 is an affirmative reply. Turn 15 invites statements of agreement. Turn 16 returns to the issue of the fairness of the comparison that was previously raised by asking, "Does that sound fair?" Turns 17,18, and 19 are affirmative responses. Turn 20 is also a response to the question in turn 16 "because then we're measuring the same thing, right?"

The distributed contributions patterns in Fragments 5 and 6 are similar in that there are contributions distributed across individuals that are brought together in a following initiate-response turn pair. In Fragment 5 (I^nIR) we saw initiations distributed across individuals that were proposing suggestions for courses of action to solve a problem and in Fragment 6 (IR^nIR) we saw responses that were distributed across individuals that were clarifications of a problem. Of particular relevance to the argument in this paper is that the distributed contribution patterns occurred during collaborative problem solving regardless of the players involved in staffing the positions in the turn-taking sequence. In Fragment 5 the players who staffed the positions were the teacher and the expert and in Fragment 6 the players who staffed the positions in the turn-taking sequence were the teacher and students.

Discussion

This study was designed to investigate the relationship between grammatical forms, institutional position (teacher, student), and topic-specific situations in lesson forms other than teacher-directed whole-classroom talk, specifically during different parts of a scientific investigation. The particular context of the investigation was a project designed to assist teachers in developing more dialogic forms of verbal intercourse (in the sense of Bakhtin), that is, forms of exchange that do not merely expound truths (as in the late Socratic dialogues) or ascertain whether the person tested knows the truth (as in the IRE pattern). The situations, distribution of discourse patterns and examples reported above are consistent with the suggestion that it is not the identity of the players who staff the posts of the turn-taking sequence that determine discourse patterns (Roth & Gardner, 2012). Discourse patterns are cultural features that participants recognize, orient to, and contribute to reproduce. Our study shows that the type of turn-taking pattern emerges in direct association with the particular situation type. That is, there is no one pattern dominating within the classroom, which could have led to the inference that the teacher implemented the form. Instead, the patterns arose in types of situations and independent of the specific staffing. The IRE pattern emerged in association with the situation where recollections are being gathered, the IRA pattern emerging in association with the situation where ideas are being gathered; the ICR/IRCR pattern emerged in association with demonstrating and practicing a skill; and the I^nIR / R^nIR patterns emerged in association with the situation of collaborative problem solving. These findings suggest a reorientation in the way observed behaviors are attributed. Here, the situation type appeared to call for discourse type. The specific participants staffing the slots in interaction types are not only subjects of the situation, but also subject to and subjected to the condition. We might therefore say that the social phenomena (i.e., the situated discourse patterns) reproduce themselves by "capturing" their staff—much as others have described "learning disability" as a phenomenon that "acquires" children (McDermott, 1993).

It has been suggested that the tension between teacher authoritative (triadic dialogue) and true dialogic discourse is inevitable and indeed appropriate for "the support of meaningful learning of scientific knowledge" (Scott et al., 2006, p. 605), that open dialogue and IRE patterns can coexist harmoniously (Wells & Arauz, 2006) and that each pattern has a function in the cultural production and reproduction of science talk (Roth & Radford, 2010). A shift to more participatory dialogic forms of teaching | learning, may be made difficult by the fact that this requires the possibility to arrive at truths that were not previously established (Bakhtin, 1984). The present work suggests ways that teachers could be

supported within the classroom through the provision of guiding materials that create new situations and therefore allow new patterns to arise. For example, in the case of Type A patterns described here, the materials might shift the class further away from the predominance of IRE patterns to IRA patterns by focusing more frequently on the collection of student ideas (Situation 1b), rather than collection of student recollections of past events (Situation 1a).

It is generally assumed that teachers hold on to the IRE pattern for control reasons and efforts to make classrooms more equitable places often involve teachers in professional development that aims to change their intentions, and ultimately classroom talk (Sedovak et al., 2016). This study supports the idea that more than good intentions are needed. If patterns of classroom talk are cultural phenomena that emerge out of particular situations in classrooms (Roth & Radford, 2012), then one way to help bring about an alteration in the patterns of classroom talk might be to focus on changing the particular situations that teachers and students are engaged in. Support materials like those used in the Steps to Inquiry project could be refined to create particular situations from which a range of discourse patterns can emerge. The materials could more specifically ask teachers to collect the ideas of the students and to acknowledge them by writing them on sticky notes and attaching them to a poster; to demonstrate skills and give students opportunities to practice them; and to solve problems such as deciding on a dependent variable to measure.

Our future work focuses on temporally changing dialogue patterns in classrooms where teachers and students are supported in the transition to student-centered inquiry by the tools of the Steps to Inquiry framework. We propose that just as classroom discourse is affected by classroom artifacts (Roth, McGinn, Woszczyna, Boutonné, 1999), or the physical space of the classroom (Roth & Hsu, 2014), tools of the framework organize the situations of teachers and students and through engaging in these situations, more equitable dialogue patterns can emerge.

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Appendix

List of Transcript Notation Symbols modified from Atkinson and Heritage (1984)

Transcript Notation Symbols	Definition
.	A period indicates a stopping fall in tone, not necessarily the end of a sentence
,	A comma indicates a continuing intonation not necessarily between clauses of sentences
?	A question mark indicates a rising inflection, not necessarily a question
!	An exclamation point indicates an animated tone
:	A colon indicates an extension of the sound or syllable it follows (more colons prolongs the stretch)
=	When there is no interval between adjacent utterances , the second being latched immediately to the first(without overlapping it), the utterances are linked together with equal signs
> <	When part of the utterance is delivered at a pace quicker than the surrounding talk, it is indicated by being enclosed between " less than" signs
o o	A degree sign is used to indicate a passage of talk which is quieter than the surrounding talk
[[ ]]	Utterances starting simultaneously are linked together with either double or single left hand brackets
[[ ]]	
[ ]	When overlapping utterances do not start simultaneously, the point at which the ongoing utterance is joined by another is marked with a single left hand bracket , linking an ongoing with an overlapping utterance at the point where overlap begins
[ ]	
-	A short untimed pause within an utterance is indicated by a dash
↑↓	Marked rising and falling shifts in intonation are indicated by upward and downward pointing arrows immediately prior to the rise or fall
(2)	The duration of a pause is indicated by a number (of seconds) inside parenthesis