Investigating the discursive interactions in the elementary science classroom

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Abstract. This study explored three aspects of classroom discourse that was conducted in elementary science classroom by a Vygotskian manner. Disciplinary content of conversations was matter (atomic structure) and modelling. Through a validated analytical framework, communicative approaches, teaching purposes and patterns of interactions were analysed. It was found that the teacher enacted both authoritative and dialogic sides of teaching episodes. Regarding teaching purposes, the teacher guided the students for engaging in a travel between micro (part), macro (whole) and symbolic (communicative) dimensions by negotiating atoms and modelling. Regarding teaching purposes, the teacher directed the students to interrogate challenges to compose models that were expected to incorporate reality. Regarding patterns of interactions, teacher-student exchanges were pervasive among others (e.g., student-student). These findings were discussed by taking current theories of classroom discourse into account and recommendations were offered for teachers' professional development.
Keyword: Communicative approaches, teaching purposes, patterns of interactions, classroom discourse, modelling

INTRODUCTION

Science classrooms are considerably complicated places in which teacher and students have countless verbal and non-verbal interactions. In the classroom, intellectual outcomes of students are mostly determined by disciplinary talks between teacher and students (Mortimer & Scott 2003). In this context, learning and development have been attached to a novel type of psychology: discursive psychology (Bruner, 1990). This movement is also called as discursive turn in psychology. Lev S. Vygotsky and his contemporaries have substantially contributed to its scope by establishing the norms of sociocultural theory (John-Steiner & Mahn, 1996; Vygotsky, 1978; 1981). To make a further contribution to the analytical aspects of the classroom discourse handled for teaching science at the level of middle school, in this study, talks or discursive interactions between a science teacher and his students were delved into. In shaping and delimiting the scope of the analysis of talks, a framework that is detailed later was applied. In the next section, Vygotskian science learning and teaching and dimensions of the framework are introduced and elaborated. Generally speaking, this study purposed to investigate three aspects of the classroom discourse by a combined and pragmatic manner. Three aspects can be considered as teaching purposes, patterns of interactions and communicative approaches. Justification for the study will be introduced within the context of theoretical framework by taking these three aspects of classroom discourse into account. This study attached importance at least for two reasons. First, classroom discourse, as indicated in the systematic review of Howe and Abedin (2013, p. 328) on classroom dialogue, has been rarely inquired into and awaited further research .The current study incorporated Turkish context as a specific research setting for this inquiry. Secondly, previous attempts, except a few (e.g., Mortimer & Scott, 2003), considered reduced or narrower aspects of classroom discourse instead of adding more perspectives to generate broader interpretations regarding the nature and structure of classroom talks and discourses. To fill the gap in this field of research, this study aimed at portraying a holistic picture of classroom discourse by systematically and pragmatically attaching three aspects to each other.

Theoretical Underpinnings

Learning and Development: From Intermental to Intramental

In Vygotskian context, learning a (scientific) phenomenon is a process in which an individual acquires thinking and talking system of a group of thinkers and talkers, for instance, scientists (Vygotsky, 1981). Learning and development are conceptualised in two planes: intermental processes (interpsychological) and intramental processes (intrapsychological plane). According to Vygotsky (1981), higher mental functions of a pupil are consequences of ongoing and simultaneous interactions of two planes. On the interpsychological plane, teacher and students rehearse and perform various social languages (Bakhtin, 1986) through diverse semiotic mechanisms (symbols, diagrams, graphics, gestures, intonations, and mimicking) as in the forms of speech genres. On the intrapsychological plane, following the internalisation of the reproduced phenomena among the group members, individual thinking as the appropriation of the previously negotiated concepts for individualised schemes is performed (Vygotsky 1978).

Thus, learning is the process of internalising (or appropriating) socially shared verbal and non-verbal activities. At the outset, individuals share their ideas by interthinking (Mercer, 2010). Proposed ideas then may be altered, modified, enlarged or falsified through social negotiations of meanings on the interpsychological plane. After making all ideas explicit on the intermental plane, it is the time for appropriating intellectual consensus attained through social negotiations for individualised purposes and applications (Mercer & Dawes, 2014). Different individuals may have different internalisation processes (Mortimer & Scott, 2003).

Learning can therefore be conceptualised as a journey from intermental plane (social, external, without) to intramental plane (individual, internal, within). In other words, learning a phenomenon, as Vygotsky (1978; 1981; 1987) indicated, is described as transformation of socially shared thinking and talking activities into internalised processes. However, internalisation should not be restricted only to concept formation process through simultaneous two-way interactions between the social and individual planes. It transcends concept formation and requires formation of consciousness as mind change or enlargement of conceptual ecology of an individual (El-Hani & Mortimer, 2007; John-Steiner & Mahn, 1996; Mortimer, Scott & El-Hani, 2012).

For example, assume that in a science classroom, a student has the perception that plants are fed from the soil they live in. On the contrary, it is scientifically proved that plants are not fed from the soil they live in but are capable of producing nutrients by photosynthesis. Expectedly, students may believe that plants grow up similar to humans and they do not feel uncomfortable about this idea (perception). This is because students observe plants in their everyday life and frequently witness that plants grow up by relying on outside nutritional sources like mammals. Indeed, these perceptions about plant nutrition are not completely wrong. In the level of *senses* (spontaneous observations and conversations with others), with the eye of pupils, it seems that plants depend on externally oriented nutrition. Nevertheless, there is a transformation of external outputs (e.g., sunlight, CO_2, water, etc.) during photosynthetic processes to produce, for instance, apples as an end-product. This type of conceptualisation of plant nutrition requires *meaning making* or *concept formation* in addition to senses. However, senses of a pupil, as mentioned, may not be completely wrong. Senses of pupils are only incomplete and should be modified or enlarged. Through social negotiations of meaning on the intermental plane, students and teacher rehearse a more scientific and formalised thinking and talking. In these internally persuasive social negotiations, students' propositions would become common, shared and explicit, and if needed, are modified and enlarged.

In this context, the question is that how students will be externalising internalised concepts about, for instance, plant nutrition. Each student's externalisation may be different from others' verbalisations, however, this does not mean that each individualised internalisation signifies contradictory aspects of phenomenon. For appropriate contexts, students may externalise and apply the internalised ideas (thinking tools) on the intramental plane. This is the process in which not only concepts are formed, but students construct consciousness (e.g., "My

ideas do not work well in illustrating nutrition of my flower, therefore, I should change/modify them"). Accordingly, Leontiev (1981) stated that "the process of internalisation is not the transferral of an external activity to a pre-existing, internal "plane of consciousness": It is the process in which this plane is formed." (p. 57).

In a similar vein, Mortimer, Scott and El-Hani (2012) and El-Hani and Mortimer (2007) proposed that internalisation is a two-step process in appropriating socially shared activities. Mortimer and his collaborators described internalisation as (i) "enriching an individual's *conceptual profile*, and (ii) becoming aware of the *multiplicity of modes of thinking* that constitutes a profile as well as of the contexts in which they can be applied" (Mortimer et al. 2012, p. 235-236; italics added). To put it differently, internalisation of an idea is to have a new conceptual profile of a concept for appropriate contexts while enhancing a meta-awareness pertaining one's modifications, enlargements or alterations on his or her prior mental states.

In the current study, teaching science concepts was accepted as inviting the students to appropriately and gradually internalise the outcomes of the public performance (intermental plane) that was held between the teacher and students or among them (students). Moreover, in this study, it was acknowledged that the students' prior opinions were not truly and completely altered or shifted since they had also incorporated overlapping ideas with the scientists' social languages. Thus, three aspects of the classroom talks were examined by taking above-located specifications of the classroom discourse.

Two Types of Concepts: Spontaneous and Scientific

For characterising (science) teaching and learning, Vygotsky (1981) also suggested spontaneous and scientific concepts. When a pupil interacts with adults or peers, s/he involves in everyday experience and acquires a specific social language incorporating a social-pragmatic value (Mortimer et al. 2012). For spontaneous concepts, there is no process aimed specifically at mastering them (Scott, 1997). Scientific concepts differ from spontaneous concepts and are formed by regular instruction. As Vygotsky (1987) explicated, "the birth of the scientific concept begins not with an immediate encounter with things but with a mediated relationship to the object" (p. 219).

Based on spontaneous and scientific concepts, social language concept has expanded instrumentality of Vygotskian perspective. According to Bakhtin (1986), a social language is "a discourse peculiar to a specific stratum of society (professional, age group, etc.) within a given system at a given time" (Holquist & Emerson, 1981, p. 430). For instance, as a member of scientists' society, a solid-state physicist considers a glass through existence of intermolecular forces and electronic interactions among these forces. Alternatively, a glass blower deals with the artistic aspects of the glass making processes. For the solid-state physicist and glass blower, realities of glass within social, cultural, historical and contextual worlds influence their (solid-state physicist and glassblower) ways of thinking and talking. The former discerns the glass through scientific experimenting (thinking) accompanied by a particular talking (e.g. states of matter, intermolecular forces, atoms, quantum). The latter would discuss how glass blowing should be performed to design state-of-art creations as s/he has artistic design concerns while thinking about how to shape the glasses aesthetically by applying specific glass-blowing techniques. This example directly reveals intimate relation between thought (ways of thinking) and language (ways of talking). As a whole, different learners (e.g., students) display specific thinking-talking systems that may be different from other learners' (teachers, scientists) thinking-talking systems. In this study, while the teacher was introducing the science content to the students, there were at the least two featured social languages within the classroom discourse.

Purpose of the Current Study

Differences and communalities between spontaneous and scientific concepts can be applied in a broader manner for effective science teaching. While learners consider spontaneous concepts in

accounting for a phenomenon, scientists operate a more formal language (Scott, 1998). Pupils with spontaneous concepts hold a specific social language (thinking-talking system) while scientists make an alternative (often broader) formalised social language salient regarding same concepts. For instance, when a child becomes tired after playing tag, s/he can think that the activity was energy consuming. This is an articulation of a social language that is transmitted to individuals by adults or peers and eventually shape everyday thinking and talking (everyday social languages) of individuals. However, an expert in biological energy systems explains the process of a human becoming tired by taking the energy transformations (e.g. aerobic respiration, consuming and producing ATP) into account that displays a distinctive thinking-talking style (social languages of science/scientists/experts). Indeed, this thinking-talking style is purposed for science learning.

There are two social languages that may be alternative to each other: "everyday social languages of learners" (spontaneous concepts) and "social languages of scientists" (formalised concepts) (Scott, 1998). In science classrooms, mostly, these two types of social languages are contradictory (Leach & Scott, 2003). When differences (contradictions) between social languages are infused into instructional setting, there would be inevitable pedagogical-discursive tensions for science teachers (Leach & Scott, 2003; Mortimer & Scott 2003; Mortimer, 1998; Scott 1997; 1998). When science teacher neglects everyday social languages of learners, teaching science is conceived as taken-for-granted. This is because the job of the teacher is only seen to transmit canonical knowledge of science as ultimate truths. This type of discourse incorporates a social language favouring scientific point of view. However, when science teacher considers everyday social languages of students, teaching science would be more sophisticated. To support, there would be conceptual deviations from teacher's teaching agenda when the science teacher acknowledges and involves everyday social languages of learners. Science teaching should integrate two alternating social languages to initiate, maintain and finalise discursive journey. In this sense, to manage discursive tensions emerged between alternating social languages, there would be specific mechanics of classroom discourse that were deeply explored in the current study. In this study, it was targeted to examine how a science teacher handled a discursive journey from everyday social languages of students to scientific point of view. For characterising the mechanics of the classroom discourse, an analytical framework that has been stimulating and eye opening for the researchers to delve into different aspects of classroom dialogue was used. The framework and justification of the study are presented in below section.

Analytical Framework and Justification for the Study

This study adapted sociocultural perspective with a Vygotskian manner (John-Steiner & Mahn, 1996). It would be therefore plausible to use a sociocultural framework to explore the mechanics of classroom discourse. In their book, named Meaning Making in Secondary Science Classrooms, Mortimer and Scott (2003) introduced a framework to characterize how meaning making are prospered by teacher and students. The framework is based on assertions of sociocultural theory and follows a Vygostkian perspective. The framework was structured through a validated on-going research program (e.g., Mortimer, 1998; Mortimer & Scott, 2003; Scott, 1998). It includes five aspects (Table 1).

Table 1. *Five aspects of the analytical framework*

Focus	1.Teaching purposes	2.Content
Approach	3.Communcative approach	
Action	4.Patterns of discourse	5.Teacher interventions

The centralized aspect of the framework, "Communicative Approach", was particularly taken into account. "Teaching Purposes" and "Patterns of Interactions" aspects of the framework were also considered to systematise the mechanics of discursive interactions.

Teaching Purposes

In a discursive journey, a teacher may have diverse teaching purposes that are object to change any time. For instance, in initial phases, a science teacher may open up with a problem that may be related to a particular phase of a lesson. The teacher may also explore diversity within students' responses. The teacher may then introduce and develop a scientific story. These teaching purposes were already observed in the study of Mortimer and Scott (2003). In this study, apart from Mortimer and Scott's (2003) study, a more in-depth classification of teaching purposes is presented. First research question is given below.

1) Which teaching purposes are featured, regarding the science content being taught, by different phases of the discursive journey?

Patterns of Interactions

Another aspect of the framework considered in this study is patterns of interactions. Basic approach to fragment teacher-student discursive exchanges is characterised as triadic dialogue (Mercer and Dawes 2014). Triadic dialogue is denominated as Initiation-Response-Evaluation (IRE). Consecutively, teacher initiates conversation through, for instance, a question ("I" move), students then provide a response ("R" move) and lastly teacher evaluates students' responses ("E" move) (Lemke, 1990; Mehan, 1979; Sinclair & Coulthard, 1975). For "E" move, teacher may provide an evaluation as well as offer a follow-up statement or another question; if not, s/he may give a feedback. Therefore, IRE-based exchanges may be changed into IRF where "F" move stands for follow-up or feedback. In this study, the streaming of classroom discourse was fragmented by triadic dialogue to pattern orientations of discursive interactions.

As a literature-based criticism, IRE-based exchanges have not been examined by researchers through integrating teacher-talk to student-talk (Aguiar, Mortimer & Scott, 2010; Cazden, 2001; Duschl & Gitomer, 1997; Lemke, 1990). In other words, dependency between teacher-talk and student-talk have been absent in most studies including an IRE-based analysis (Sunderland 1996; 2000). Thus, in the current study, patterns of interactions were investigated in a contingent manner by attaching teacher-talk to student-talk. The talks of teacher were linked to the talks of students by taking diversifying patterns of interactions into account. Second research question is stated below.

2) What are the patterns of interactions that are emerged in the streaming of the classroom discourse?

Communicative Approaches

According to dialogism concept (Bakhtin, 1981), classroom discourse can be authoritative and dialogical. An internally persuasive discourse is open to alternative ideas. In contrast, authoritative discourse does not permit bringing together and negotiating alternative ideas (Buty & Mortimer, 2008; Mortimer & Scott, 2003; Scott, Mortimer & Aguiar, 2006).

Table 2. *Four classes of communicative approaches**

	INTERACTIVE	*NONINTERACTIVE*
DIALOGIC	Interactive-dialogic	Noninteractive-dialogic
AUTHORITATIVE	Interactive/authoritative	Noninteractive/authoritative

Modified from Scott, Mortimer, & Aguiar (2006)

To explicate, "a sequence of talk can be dialogic or authoritative in nature, independent of whether it is uttered individually or between people. What makes talk functionally dialogic is that different ideas are acknowledged, rather than whether it is produced by a group of people or by a single individual." (Buty & Mortimer, p. 1639). In other words, social interactions

between two individuals do not mean that discourse is dialogic. Based on this, communicative approach (Mortimer & Scott, 2003) includes two dimensions; non-interactive/interactive and dialogic/authoritative (Table 2). For non-interactive/authoritative dimension, there is no verbalised-socialised exchanges between teacher and students. In this sense, teacher tends to introduce a single point of view that mostly favours scientific point of view. For interactive/authoritative dimension, there may be verbalised-socialised exchanges, however, teacher selects some student-led ideas that are neater to scientific point view while eliminating other ideas that are not overlapped with canonical knowledge of science. For non-interactive/dialogic dimension, there may not be verbalised-socialised exchanges. But, the teacher welcomes alternative or contradictory worldviews. Thus, dialogicity of a discursive journey should be understood whether enacted discourse incorporates alternative or contradictory points of views. For interactive/dialogic dimension, there may be both verbalised-socialised interactions and teacher acknowledges students holding alternative points of views in addition to scientific point of view. In this study, possible fluctuations among four classes of communicative approach were detected qualitatively and quantitatively. It was therefore more probable to see interplay among classes of communicative approaches that is unique to the current study. Based on this, third research question is indicated below.

3) How can the teacher work with the students to address the diversity of ideas emerged in the classroom discourse?

METHODS

Research Approach

In this study, the researcher was less concerned with organisational structure of spoken language and examined conversations' contents, functions and varying ways of joint understanding that were embedded in the social context, over time (Mercer, 2005; 2008). Additionally, all verbal and non-verbal discursive interactions were enacted by the class members within a specific instructional content and context. Thus, a case study approach (Yin, 2003) was conducted to capture the teacher's and students' verbally-oriented and socially-determined interactions for individual meaning making in both dialogic and monologic manners. A case study is one of the best tools for providing "intensive descriptions and analyses of a single unit or bounded system such as an individual, program, or group" (Merriam, 1998, p. 19). Through a case study, the intention was to represent reasons of the teacher's orientations in creating particular types of teaching purposes, communicative approaches and patterns of interactions. The researcher was of the idea that revealed teaching purposes, communicative approaches and patterns of interactions would be unique to the study's case (a single unit) that was established by the collective efforts of the participants. Moreover, in this study, the teacher were subjected to a particular instructional pedagogy (e.g., Argument-based Inquiry; ABI as a co-constructivists teaching) within a specified curriculum-based content (atoms and modelling). As a whole, a case study was conducted based on the proposal of Merriam (1998), as she indicated that case studies mainly focused "on a particular situation, event, program, or phenomena" (p. 29).

Participants

An experienced science teacher and his 26 sixth-grade students (Females = 12, Males = 14), aged 11-12 years were the participants. The students were taught in a private school. The teacher was a PhD student in science teaching. The teacher worked for an international project for disseminating student-centred teaching. He was on a professional journey to become a teacher educator by designing, planning and implementing professional development programs for elementary and secondary science teachers. A purposeful sampling was used for specific research-based goals. At the outset, an experienced science teacher was involved in the study,

since he was a better implementer of the ABI activities. He was also informed about instructional purposes the study. Thus, the teacher tended to behave with a systematic and pragmatist manner to inform the study. To put it differently, he intended to create a *variance* regarding teaching purposes, patterns of interactions and communicative approaches allowing for a fine-grained analysis of classroom discourse. It was more convenient to meet the objectives of the current research by collective efforts of described science teacher (educator). As an important note, this could be considered as a strong threat for a case study approach adopted in the current study. However, it was truly scaffolding and instrumental to capture or grasp any data pieces as the *differentiated* (three) aspects of classroom talks investigated in this study. In other words, the researcher was striving for establishing a *saturated* qualitative data set to inform and enrich the outcomes of the study to present more holistic and fine-grained interpretations. Thus, this may not be considered as a threat instead it was a pragmatic intervention of the researcher to gather more sophisticated discursive data in shedding light on the truly diversifying teaching purposes, communicative approaches and patterns of interactions. This study was a naturalistic inquiry as a case study that was not deteriorated through a concrete external intervention. The purpose of the researcher was only to enrich the insights of the case as a bounded system to approximate to the reality.

Moreover, the students normalised video recording as they were both informed about and familiarised to video-recording sessions that avoided any Hawthorne effect. More importantly, as Cavagnetto (2010) reviewed, there are a few studies on how social negotiations of meanings and individual meaning making are actualised especially for elementary and middle school students. Thus, sixth graders were involved in this study in response to the gap in the literature regarding participants who are in a specific cognitive development stage. In the extended review, Cavegnetto (2010) revealed that classroom discourse studies devoted to older student groups such as secondary students (e.g., Mortimer & Scott, 2003). Thus, this study aimed at including small graders to show that they were able to contribute to classroom discourse when the teacher made wise and varied combinations between science teaching purposes, communicative approaches and patterns of interactions.

Argument-Based Inquiry (ABI) Implementation

ABI approach is a research-based frame for inquiry-based science teaching activities (Cavagnetto & Hand, 2012). ABI approach presents a framework to guide students' inquiry activities and provides meta-cognitive support to encourage students to ponder about data for creating their own evidences in a heuristic sense (Cavagnetto, 2010). The content of the implementation was atoms and modelling. This topic was determined, because it was considerably productive in capturing various student-teacher exchanges that informed this study (Mortimer, 1998). The major purpose of the teacher was to create an argumentative context in which the students were composing their theoretical models (Buty & Mortimer, 2008) to understand how matter behaves in specific states. Three cycles of the implementation are detailed below.

Initiating-Developing-Expanding: In this phase, the teacher pooled student-led ideas about atoms and modelling as well as tried to convince the students that they might present a less elucidatory thinking and talking style. The teacher presented mind-stretching examples for convincing the students that they could hold conceptual, epistemological and ontological conflicts regarding the topic. The teacher deliberately made students' cognitive contradictions explicit. Thought-provoking teacher questioning (e.g., playing devil's advocate role) compelled the students to work through about their cognitive contradictions that could be eliminated by designing and negotiating theoretical atomic models. Three types of cognitive contributions are exemplified below.

a) *Conceptual contradictions*: The teacher presented the idea that if substances incorporate atoms, when someone holds a pen, s/he touches atoms of the pen. The students did not accept this idea and found it cognitively disturbing. The students supposed that atoms are embedded in substances.

b) *Ontological contradictions:* The students negotiated the empty space among molecules to categorise the state of matter. The teacher then proposed if molecules incorporate empty spaces, what other stuffs fill or infuse in the spaces.

c) *Epistemological contradictions:* The student-led modelling was interrogated by the teacher and other students whether being composed models reflect actuality of the nature and structure of atomic configurations.

In this cycle, responsibilities of the teacher were to
- *listen actively to the students,*
- *make students' thinking fallacies explicit,*
- *pose scaffolding questions to guide the students to alternative ways of thinking and talking.*

The role of the students was to design models regarding
- *positions of atoms and molecules for specific substances or solutions,*
- *intermolecular forces,*
- *particular states of the matter, matter combinations as solutions,*
- *solid, liquid and gas formations of solutions (e.g., when the students modelled a condensing or evaporating liquid salty water.)*

Experimenting or Modelling: In this cycle, the teacher supported the students to reconsider their initial models' irrelevant parts (Buty, Tiberghien & Le Maréchal 2004; Mortimer, 1998). In this phase, the students composed models and were engaged in reasoning about them to generate tangible evidences to modify or change their initial theoretical models. To notice, discursive quality of the next phase (whole group negotiations) was related to the diversity of the produced models within the second phase. To explicate, some student groups were working on similar models. By closely monitoring student groups, the teacher therefore prompted the students to re-ponder about alternative aspects of atoms and modelling to generate conceptual variations in student-led ideas in order to augment the scope of further negotiations.

Finalising-Reviewing: There were student-proposed competing theories regarding the properties of atoms (what aspects) and epistemological nature of models or modelling (how aspects). The teacher therefore contrasted presenter groups' model-based arguments. In this context, discursive purpose of the teacher was to increase student-student negotiations by comparing students' mutually exclusive model-based assertions. For instance, two different student groups modelled intermolecular forces of a water-salt solution. However, they introduced distinctive models even though they tried to account for the same intermolecular forces. These were the most generative moments for the classroom discourse.

There were several discursive attempts of the students in this cycle:
- *presenting their modelling to competing groups,*
- *involving in rigorous negotiations regarding atoms and modelling,*
- *criticising others regarding relevancy of introduced assertions and actuality of models.*

These attempts of the students resulted in frequent verbal exchanges with others and the teacher. To put it differently, each group tried to convince other groups that their models reveal reality with a better way or are closer to reality. The teacher deliberately invited the students to criticise, evaluate and judge their classmates' thinking in the form of modelling.

Data Source

Video recording of the in-class ABI implementation was data source allowing in-depth investigation of three aspects of the classroom discourse. An assistant who located cameras to the best points for capturing all discursive exchanges technically aided the teacher. The assistant walked around classroom with camera to record one-to-one interactions. The participants were informed about purposes of video recording. All participants signed consent forms. The students were also accustomed to the video-recording process. As members of the abovementioned international project, the students had been filmed many times. The video-recorded ABI implementation lasted 200 minutes.

Data Analysis

Data analysis consisted of three steps: (i) creating episodes, (ii) coding procedures, (iii) counting procedures.

Creating episodes: Prior to the analysis, the videotaped data was verbatim transcribed incorporating 432 talk turns. The purpose of the current study was to reveal the changes in three aspects of classroom discourse along a continuum. The whole transcript therefore was divided into sub-topical episodes containing less talk turns. The division was crucial in determining cumulative proportions of three aspects of classroom discourse. In separating a sub-topical episode from others, some specific teacher-led utterances were considered. As an example;

> "**Anyway, let's return to beginning.** Now, a friend of yours previously mentioned that atoms are gluey. Let's discuss this idea, what do you think about this?" (Turn-30, first episode; interval: Turn-1 to Turn-30; containing 30 talk turns).

This was where the teacher and students passed into next episode. The underlined and bold utterance displays that there is a new initiation for (sharp passing into) the next episode.

Coding procedures: For 432 talk turns 26 episodes were created. Clarification of three aspects of the classroom discourse were carried out by systematic observation (Mercer, 2010), being a branch of discourse analysis. Mercer (2010) proposed that researchers can develop their own categorising system, or they can adopt an off-the-shelf system. Based on this suggestion, a theory-based and data-driven coding framework borrowed from Mortimer and Scott (2003) was used. Through strictly abiding by the framework and streaming of discursive exchanges, the researcher trained himself to identify three aspects of the classroom discourse that are corresponded to each category indicated in the framework. The researcher thus worked on the transcripts of video-records and assigned what he saw and heard to the categories. In other words, the researcher assigned analytical codes to the utterances given by the teacher and students as previously defined within the categories of the framework.

Counting procedures: As second sub-phase of a systematic observation (Mercer, 2010), frequencies of communicative approaches, teaching purposes and patterns of interactions were counted. The major aim was to obtain cumulative proportions or relative occurrences of each aspect of the classroom discourse. It was important to quantify relative incidences to pattern distributions of the three aspects along the discursive journey.

Trustworthiness of the Study

Even though collected data was restricted to, video-recording, other techniques were utilised to meet the standards of validity. First, to attain a theory/perspective triangulation, distinctive but complementary theoretical perspectives (e.g., Vygotskian teaching and learning, conceptual profiles, sociocultural theory of learning and teaching) were taken into consideration for examination and interpretation of the data (Angen, 2000; Denzin & Lincoln 2005; Patton, 1980). Second, the researcher negotiated ongoing investigational processes (e.g. data collection,

analysis and interpretation) with his colleagues that served as peer debriefing (Lincoln & Guba, 1985). This supported the dependability of the research.

RESULTS

In this section, at the outset, an example analysis of the classroom discourse is presented. Then, cumulative proportions regarding three aspects of the classroom discourse (teaching purposes, patterns of interactions and communicative approaches) are presented and interpreted. As mentioned, each aspect of the classroom discourse is accompanied with a research question addressed in this study. Thus, a question-based introduction and interpretation of the findings is presented.

An Example of Discursive Analysis

In Table 3, an array of discursive interactions (9th sub-topical episode) is displayed. There are three columns in Table 3 showing talk turns, contributors (teacher, students) and articulations of the contributors.

Table 3. *Discursive analysis of Episode-9*

Talk turns	Contributor	Patterns of interactions	Utterance
174	Teacher	Initiate(I)	Now! Do we accept that salt molecules penetrate into water molecules for salt-water solution?
175	Student (all)	Response(R)	Yes, Sir! (several simultaneous replies)
176	Teacher	Follow-up questioning(F)	OK, I agree with you. You also mentioned… Water molecules surround salt molecules. Well, what if I freeze this salty water?
177	Student-3	Response(R)	It becomes solid, I mean… Salty-ice.
178	Teacher	Follow-up questioning(F)	So, when it solidifies what would be positions of "salt as a solid" and "water as a solid"?
179	Student-3	Response(R)	Sir, we can only see salt this time. Because it only changes physically. Therefore, it does not change.
180	Teacher	Follow-up questioning(F)	However, right now, salt within water is solid…
181	Student-11	Response(R)	But! Sir! Well, friends! If it becomes solid this time, spaces will be reduced. Then, how will it be?
182	Teacher	Follow-up questioning(F)	What will happen, then? Will salt particles escape when it freezes?
183	Student-11	Response (R)	Then, salt will go to corners of water as solid.
184	Teacher	Follow-up questioning(F)	However, why go to the edges? Now! I am drinking it and it tastes as a salty water. Are salt particles dispersed homogenously? Well, what if I take a drop of water from this solution and analyse it? Would it be same?
185	Student-4	Response(R)	For example, there are sands under seas… So, then sands could not penetrate into water. Therefore, salt could penetrate into.
186	Student-8	Response(R)	Salt particles within water particles. Water molecules within salt particles. Which one? Then, we can think same for sand and water. So, if sand and water does not mix up, then sand is getting into water.
187	Teacher	Follow-up questioning(F)	Did you want to say that salt particles do not permit sand particles to penetrate into water?
188	Student-8	Response(R)	No! We said that sand is dispersed to whole sea. Then, we should think that sand is getting water.

In this episode, the teacher and students negotiated the differences between modelling a "*liquid* salty water solution" and "*frozen* salty water" (ice with salt particles). Within Turn-178,

the teacher asked for whether there would be differences or communalities between previously mentioned two types of formations regarding modelling. After collecting a few responses (Turn-179, Turn-180), the teacher prompted the students to focus on Student-11's utterance (Turn-181). Student-11 mentioned about a decrease among spaces within molecules when water is frozen. Within Turn-182, the teacher challenged the student-led utterance by proposing that whether salt particles are jumped out of from a freezing water. Then, Student-11 (Turn-183) tried to advocate her initial position by imagining that salt particles would be placed at the edges of freezing water. The teacher, for the second time, challenged by indicating that within a salty water, salt particles are dispersed homogenously and taste of salty water is the same within any sampling of it. Student-4, within Turn-185, presented an alternative proposal incorporating molecular interactions among water, salt and sand particles.

All sub-topical episodes were examined like Episode-9 to detect qualitative variances and quantitative proportions of teaching purposes, patterns of interactions and communicative approaches. For instance, regarding *teaching purposes*, in Episode-9, the teacher tried to promote the students to engage in a zigzag (back & forth) process between macro and micro behaviours of solutions. Particularly, within Turn-182 and Turn-184, the teacher tried to prompt the students to think about materialistic influences of micro changes on macro changes (e.g., salty water as a new physical formation in molecular scale and change in the taste of salty water in macro scale). Regarding *patterns of interactions*, there were open chains of exchanges (Table 3). As seen in Episode-9, the teacher did not evaluate the student-led responses based on scientific point of view by cutting students' initiations off when they were responding to the teacher-led questioning. Instead, the teacher resumed conversations through follow-up questioning by keeping student-led responses in mind. Thus, a specific patterning emerged as [IRFRFRFRFRFRRFRR] or [TSTSTSTSTSTSSTSS] for Episode-9. Finally, Episode-9 was coded as an interactive/dialogic episode regarding communicative approach. To support, as seen in Table 3, the teacher welcomed and acknowledged students' responses and did not directly rejected even fallacious ideas. More importantly, the teacher made a room for students' alternative thinking and talking about atoms and modelling. In addition, there was a high interanimation (Mortimer & Scott, 2003) for proposed ideas as the teacher tried to probe and challenge students' propositions to convince them that there might be more elucidatory explanations compared to their assertions about atoms and modelling.

Detected Teaching Purposes

In this section, first research question is addressed: What teaching purposes are featured, regarding the science content being taught, by different phases of the discursive journey? Qualitative variance of teaching purposes is listed in Table 4. At the outset, it can be acclaimed that there was a wide range of teaching purposes. In addition, teaching purposes seemed to be *idiosyncratic* to the content (atoms and modelling). To explicate, listed teaching purposes were enacted as topic-specific. For other science topics, teachers may perform diverse teaching purposes. Mortimer and Scott (2003) described teaching purposes in an overarching or generalised sense as *content-independent* and *context-independent*. In this study, it is also confirmed that, for diverse science topics, there may be diverse teaching purposes while initiating, maintaining and finalising discursive exchanges. To put it differently, this study proved the fact that teaching purpose could be *content-sensitive* and *context-sensitive*. Two types of teaching purposes were salient and mostly applied by the teacher (Table 4). The teacher pervasively performed a teaching (discursive) purpose as *a discursive travel around micro and macro perspectives* (46.4%). To explicate, the teacher with this teaching purpose prompted the students to reason about part-whole relations. To do this, the teacher promoted the students to think about how changes in molecular scales (e.g. separating the solute into its individual components, overcoming intermolecular forces in the solvent to make room for the solute) are reflected upon physical or materialistic scales (e.g., allowing the solute and solvent to interact to form the solution).

Table 4. *Variance among the teaching purposes*

Teaching purpose	Episodes sequence	*f* (%)	Descriptions
1. Exploring variances in students' ideas	1, 13	2(7.69)	The teacher only pooled and consolidated student-proposed ideas by not interrogating them
2. Identifying positions or locations of atoms within substances	2	1(3.85)	The teacher negotiated positions of atoms by considering whether atoms are within substances or dispersed through surfaces of substances
3. A discursive travel around micro and macro perspectives	3,6,7,8,9,10,12, 20,21,23,24,25	***12(46.4)***	*The teacher discussed about influences of micro changes on macro changes (e.g., salty-water as a new physical formation in molecular scale and change in taste of water (salty) in macro scale); interrogation of part-whole relations*
4. Interrogating a modelling of state of matter	4	1(3.85)	The teacher discussed about proximities and distantness among molecules for different state of matter
5. Imagining spaces within atoms and intermolecular structures	5	1(3.85)	The teacher investigated what other staffs or things could fill into intermolecular spaces: what is the stuff of empty space in atoms?
6. Interrogating a modelling of water-salt solution	11	1(3.85)	The teacher negotiated physical and chemical differences and communalities between salt, water and salty-water
7. Prompting students to discriminate unrelated ideas from related ideas	14	1(3.85)	The teacher promoted the students to talk about related ideas by neglecting or eliminating unrelated claims for the sake of an internally consistent discursive flow
8. Discussing materialistic challenges to compose a model	15,18,19,22,26	***5(19.2)***	*The teacher argued about epistemological, ontological and conceptual contradictions to compose a model displaying the reality*
9. Differentiating characteristics of substances	16,17	2(7.5)	The teacher negotiated about solubility feature for differentiating a substance from others

For instance, as exemplified in Table 3, if salt particles overcome intermolecular forces of water to make room for the salt particles, within micro perspective, water must be tasted as salty, within macro perspective. To explicate, there would be homogenous replacements of water and salt molecules. Secondarily, teaching purpose as *discussing materialistic challenges to compose models* was detected frequently compare to other teaching purposes. For many discursive episodes (e.g., *episode no*: 15, 18, 19, 22 & 26; 19.2%), the teacher guided the students to think over whether constructed models represent materialistic reality. Moreover, the teacher engaged the students in discussing about need for models to portray materialistic actuality. In addition, the teacher and students negotiated whether models (or modelling) facilitated their comprehensions and imagining about solutes, solvents and solutions or whether composed models made understanding regarding topic under negotiation more puzzling and confusing.

Revealing Patterns of Interactions

In this part, findings regarding second research question are interpreted: What are the patterns of interactions emerged in the streaming of the classroom discourse? For this purpose, teacher-student and student-student exchanges were systematically observed and counted (see variances and proportions in Figure 1). [T-S] patterning signifies a sole teacher-student interaction continuing as T-S-T-S-…-T-S [e.g., I-R-*E* or I-R-*F*]. [T-S-S] patterning reveals a triadic exchange as teacher-student-student, dominated by students' responses [I-*R-R*]. [T-S-S-S]

patterning displays a quadruple of teacher-student interaction overly dominated by students' responses [I-*R-R-R*]. [S-S] patterning includes a student-led initiation and other students' responses [I*s*-R*s*: "I*s*: student-led initiation", "R*s*: student-led response"]. [S-S-S] patterning consists of three different student-led voices [I*s*-R*s*-R*s*], and [S-T] patterning includes a student-posed question to teacher who is required to provide a response [I*s*-R*t*: "R*t*: teacher-led response"].
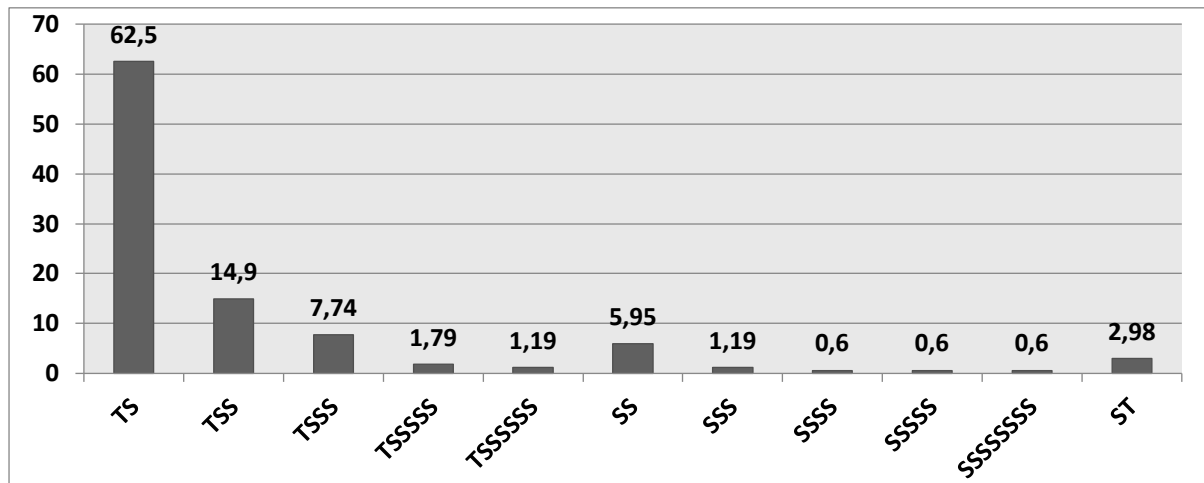

FIGURE 1. *Percentages of patterns of interaction*

Most verbal exchanges were between the teacher who enacted a follow-up questioning after a student-led response ([T-S]: 62.5%; Figure 1). About 15% of interactions were patterned as [T-S-S]. About 8% of exchanges were revealed as [T-S-S-S] as a more expanded student-student conversational flow. Less than 6% of interactions were patterned as [S-S]. This implies that most initiations for conversational episodes were controlled and regulated by the teacher. Finally, less than 3% of interactions were emerged as [S-T]. This approves that most questioning initiations were performed by the teacher.

Variances within the Communicative Approaches

In this section, findings and interpretations for third research question are presented: How can the teacher work with the students to address the diversity of ideas emerged in the classroom discourse? In Figure 2, percentages related to communicative approaches are exhibited. Non-interactive/authoritative communicative approach was not detected. This implies that all communicative transactions were socially and verbally interactive and dialogicity of the conversations (welcoming alternative points of views) was ensured to a certain extent. Non-interactive/dialogic communicative interaction was detected as less than 4%. This shows that more than 96% of all communicative interactions were verbally and socially interactive.
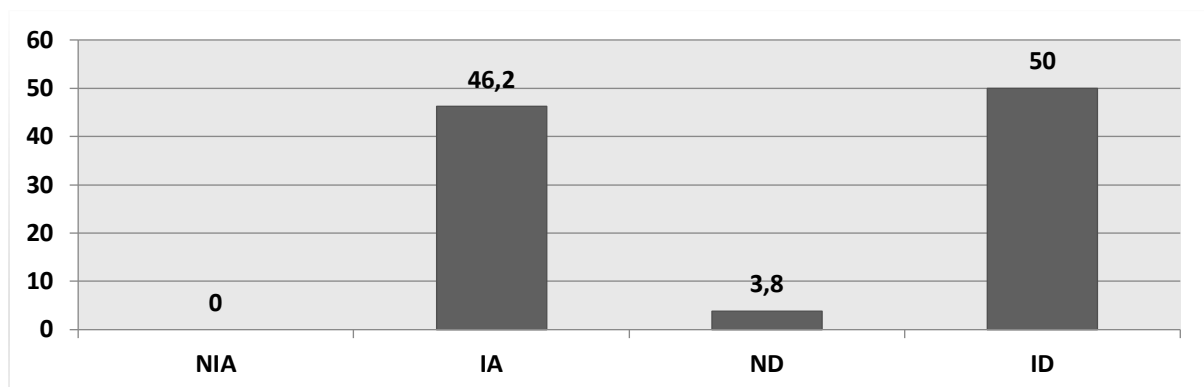

FIGURE 2. *Occurrences of four classes of the communicative approaches*

As deduced from Figure 2, proportions of interactive/authoritative (46.2%) and interactive/dialogic (50%) dimensions were occurred respectively equally. This means that within topical episodes both the students' everyday social languages (interactive/dialogic dimension) and scientific point of view (interactive/authoritative dimension) were taken into account. To interpret, the teacher seemed not to direct the students to believe in or argue about only a single point of view (interactive/dialogic dimension). However, the teacher held a teaching agenda favouring scientific point of view. Thus, he was in need of handling more authoritative communicative interactions (interactive/authoritative dimension) by not neglecting verbalised and socialised interactions with the students.

DISCUSSION and CONCLUSIONS

Three prominent conclusions guide discussion section: (i) two classes of the communicative approaches were pervasive among other dimensions; (ii) patterns of interactions were dominated by [TS] patterning; (iii) there was a wide genre of teaching purposes and two specific teaching purposes were prominent. Each featured point is discussed in light of current theories of classroom discourse.

In this study, authoritative and dialogic communicative episodes were detected in a balanced and simultaneous manner. This shows that the teacher enacted two orientations of teaching science: teacher-centred (subject-centred) and student-centred (skill-centred). At the outset, theoretical modelling through ABI implementation may be anticipated as a student-centred activity. Accordingly, in this study, the ABI implementation incorporated open-ended discursive exchanges in which the students were permitted by the teacher to negotiate their ideas with others (Cavagnetto, 2010; Cavagnetto & Hand, 2012). During theoretical modelling, the students were also involved in doing-science processes. The teacher therefore tried to keep the students away from recipe-type, step-by-step procedures as they were expected to conduct their own research.

In addition to student-centredness of theoretical modelling, the implementation was relatively pre-structured. To put it differently, the student-led models were surrounded by previously defined contents favouring curricular objectives and accountabilities (Cavagnetto, 2010; Cavagnetto & Hand, 2012) specifically on the side of the teacher. Thus, the teacher had a half flexible (open-ended) and half predetermined teaching agenda to fulfil both the implementation's discursive purposes and curricular-based accountabilities. As a result, the teacher had to put monologically oriented communicative dimension forward to direct the students to use a more formalized thinking and talking as scientists develop and apply. Monological orientation (interactive/authoritative) was accompanied by dialogically oriented communicative dimension (interactive/dialogic) in which open-ended social negotiations of meanings were frequently enacted (Leach and Scott 2003). Indeed, this ensured a harmony or rhythm (Mortimer & Scott, 2003; Scott et al., 2006) among displayed communicative dimensions. The teacher had to manage both authoritative and dialogic communications in a balanced, purposeful, functional and, more importantly, *pragmatist* manner as confirmed by other studies (Mortimer & Scott, 2003; Scott, 1998; Scott et al., 2006).

In a student-centred activity, patterns of interactions are expected to be patterned as teacher-student, in general, and as student-student, in particular. In this study, student-student patterning was less detected compared to teacher-student patterning. It seemed that the teacher tried to govern discursive interactions. This finding can be explicated by taking the *staging role of the teacher* into account (Scott, 1998). The teacher seemed to be primary person who monitored the flow of discussions and made decisions on further negotiation sub-topics. To be clear, streaming of discursive interactions was mostly legitimated by the teacher. The students were mostly responsible for responding to the teacher's questions. In other words, flows of the discussions were mostly teacher-guided and there were less student-directed initiations. In a similar vein, Hogan, Nastasi and Pressley (1999) conducted a fine-grained analysis of patterns of interactions. Hogan et al. (1999) compared students-guided and teacher-guided discussions' conceptual flows' internal consistencies. Hogan et al. (1999) found that even though more talk

took place in small student groups (regulated by the students), the students' arguments were under-articulated and piecemeal. The students were not able to recognise what they needed to clarify and present to the group members in the absence of guiding teacher discursive moves. In this sense, the teachers crystallised need and essence of discussion streaming more precisely for a purposeful meaning making (Hogan et al. 1999). Thus, TS-dominated patterning in addition to other patterning, as detected in the current study, may be accepted discursively fruitful and serviceable for classroom discourse. In this study, teacher-dominated patterns of interactions allowing for non-deviating or internally cohesive verbal exchanges might be more intellectually productive. To explicate, the teacher did not only want to negotiate ideas with a non-purposeful manner. Instead, in a rigorous sense, the teacher wanted to get somewhere by linking the students' ideas to each other for more coherent lines of reasoning (Engle & Conant, 2002).

It was concluded that the teacher enacted varying teaching purposes. Particularly, two teaching purposes were pervasive among others. Two prominent teaching purposes are labelled as "discursive travels between micro-macro perspectives" and "multifaceted nature and structure of models and modelling". This finding can be supported by arguments of teaching chemistry in particular. Talanquer (2011) asserted that terminology of chemistry (atoms, substances, intermolecular forces, bonds, solutes, etc.) are generated and communicated by three dimensions: (i)macroscopic level; (ii)sub-microscopic level; (iii)symbolic level. Three dimensions can be considered and applied for learning and teaching chemistry-based content in a powerful and productive way (Gabel, 1999; Gilbert & Treagust, 2009a). As Gilbert and Treagust (2009b) reported, the interrelated triplet (micro-macro-symbolic dimensions) has been used fruitfully in directing the work of chemistry instructors, curriculum and software developers, and textbook writers. Apart from these uses, in this study, the teacher highlighted micro and macro dimension by discursive purposes and infused two dimensions of chemistry-based thinking (atoms and modelling) into teaching processes.

More importantly, as Gilbert and Boulter (2000) and Gilbert (2005) confirmed, infusing interplay between micro and macro dimensions into teaching processes can be substantially influential on students' modelling, visualisations and imaginations. As revealed in this study, secondly pervasive teaching purpose was abstracted as "discussing materialistic challenges to compose models". It appears that when the teacher aspired to promote the students to think about micro and macro dimensions of atoms and modelling, the students were engaged in modelling and visualising processes within their background imagining. In other words, two prominent teaching purposes were enacted by an overlapped style by the teacher to support the students' modelling and discursive travels (conceptual zigzags or theoretical back-and-forth) around micro and macro worlds.

As a final note, the teacher also intended to externalise the students' symbolic worlds by prompting them to compose models exhibiting interior materialistic structures of substances. When the students conceptually think around macro and micro dimensions, they seemed to appropriate a novel thinking and talking including newly introduced jargons (e.g., molecules, intermolecular forces, atoms, solutes, solvents, and so forth). As a whole, regarding symbolic dimension, novel social language that the students began to use and apply did not serve only communicative functions, newly staged jargons were also internalised by the students in characterising atoms and modelling.

RECOMMENDATIONS

One of the most important implications of this study is for professional development of science teachers in enacting specified communicative approaches, teaching purposes and regulating patterns of interactions. In this study, it was concluded that meaning making in the science classroom is a dialogic process (Mortimer & Scott, 2003) and may not be considered as a simplified duty to be handled (Crawford, 2000). As shown, science teaching can be sophisticated requiring a continuous balance between more dialogic and more monologic communicative approaches or between mutually exclusive social languages (spontaneous *vs.* science). This therefore may ensure an instructional tension for science teachers who may not have an

awareness about the discursive tension. As a suggestion, following Schon's (1983; 1987) recommendations, in educating a reflective practitioner during professional development processes, teachers may make self-reflections on multi-layered aspects of detected dynamics of classroom discourse to systematically observe and evaluate their in-class activities. Methodologically, pedagogical-discursive awareness can be more visible through stimulated-recall sessions as core part of well-designed professional development programs (Calderhead, 1981; Nilsson & Vikström, 2015).

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