Title: “Vibration... The water molecules balanced... More like a see-saw is it?”
Let’s talk physics: Promoting meaningful discourse through disciplinary literacy instruction

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"Vibration... The Water Molecules Balanced... More Like A See-Saw Is It?" Let's Talk Physics: Promoting Meaningful Discourse Through Disciplinary Literacy Instruction

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Disciplinary Literacy and Meaningful Discourse

Abstract

In the current Singapore and global education landscape, effective communication is increasingly being emphasized as an important competency skill in the curriculum. Consequently, recent development in the area of *disciplinary literacy* focuses on how to promote meaningful talk among students and teacher in the science classroom as they jointly construct conceptual knowledge and understanding. Based on sociocultural theory studies, classroom talk is a social communicative tool using the specialized (scientific) language in action to drive specific interaction between participants for meaning making. The purpose of this paper is to investigate the impact of a disciplinary literacy teaching approach on the discursive exchanges occurring in a physics classroom. The interventions were co-designed with the teacher on the topic of waves using various strategies (e.g. scaffold practice, teacher modelling) focusing on specific literacy skills (e.g. speaking, writing); which differed from non-intervention lessons where fewer of these strategies were enacted. Using Mortimer and Scott (2003) discourse analysis framework, it was found that disciplinary literacy teaching strategies used explicitly have (1) influenced the communicative approach of the learning space to draw a balance between the authoritative voice of the teacher and the dialogic interactions to develop scientific knowledge, (2) provided opportunities in the discourse to sharpen the scientific language for meaning-making among the participants, and (3) illuminated how disciplinary literacy instruction that emphasized on different literacy skills (e.g. talking and writing) promoted effective discourse for science education.

**Keywords:** classroom discourse, disciplinary literacy, science communication, dialogic interactions, meaning making
**Introduction**

In a daily science classroom setting, the primary source of information usually comes from teacher's talk or the discourse that occurs between teacher-students or among students. Evidently the nature of talk plays an important role in shaping the students’ learning and meaning-making process. Classroom verbal discourse has gained much research interest in the education field to examine the interactions and language transactions that would mediate construction of knowledge and meaning (Lemke, 1990; Walsh, 2011). Consequently recent development in *disciplinary literacy (DL)* focuses on knowledge construction in the science classroom through promoting effective classroom talk. Prior research has shown the lack of disciplinary literacy in adolescent learners, which encapsulates specific ways of talking, reading, writing and thinking used by a particular discipline allowing learners to participate meaningfully in the social practices and accessing knowledge in the content areas (Moje, 2007). Hence the focus of literacy demands of content areas has gained growing attention in instruction and practice (Fang, 2014).

Classroom discourse is not constituted by mutually exclusive acts of knowledge transmission from teacher to student in a linear plane, rather it is comprised of complex features of international space that give a lesson or a teaching session its unique shape or 'architecture' (Heritage, 2005). So talking in class is not as simple for students as one might think for various reasons as such as they may lack self-confidence, unwilling to take risks, fear of mistakes or teacher's contributions are too vague or difficult to understand or even implicit notions of uneven distribution of turns where teacher favored listening to smarter kids talk (Lee & Ng, 2010; Tsui, 1996). Such sentiments would be shared by many teachers globally and Singapore would not be an exception where reticence class is commonly experienced. As such how does the enactment of disciplinary literacy instruction aid in transforming the teaching practice and promote meaning-making in learning science?
To date, much remains unclear about how disciplinary literacy instruction might look in practice and its discourse features remind vague. And few studies have been carried out to develop interventions that can explicitly help students develop disciplinary literacy and document the learning benefits that could be derived from the interventions. The overarching question would be how does disciplinary literacy teaching approach impact a science classroom discourse? Taking that into consideration, the research questions would be

(1) What aspects of discourse approach and patterns of interaction would be considered an emphasis of disciplinary literacy instruction?

(2) How do discourse approach and patterns of interaction foster meaning-making and sharpen the specialized language used?

Therefore, the purpose of this paper is to examine the discursive exchanges and to investigate the impacts of the disciplinary literacy teaching strategies enacted in the physics classroom with the subsequent writings from students' artefacts.

This is important in understanding the impacts of the *dialogic* process for meaning making in classroom discourse and providing appropriate disciplinary literacy teaching strategies to facilitate meaningful talk. Additionally, showing the impacts of how disciplinary literacy instruction has gradually transformed the teacher's pedagogy to provide the students a platform to actively participate in meaning-making of science concepts through scientific discourse in a rather reserved classroom environment.

**Theoretical Perspectives**

The central theoretical lens that informs our work is sociocultural theory to conceive literacy as social practices in classroom talk as a social communicative tool using the specialized (scientific) language in action to drive specific interaction among participants for meaning making. This is anchored upon Vygotsky's social development theory that emphasized on the fundamental role social interaction played in cognition development.
Vygotsky argued, "Learning is a necessary and universal aspect of the process of developing culturally organized, specifically human psychological function" (1978, p. 90), ascertaining that community plays a central role in the process of meaning-making.

Hence based on Vygotsky’s perspective on development and learning, which puts forth the notion of learning would occur in social situations. In these social contexts, ideas are shared between people mainly through talk. Consequently, each participant is able to make sense of what is being communicated in the social exchanges and the terms or language used, in consideration of multiple ‘voices’ (Bakhtin, 1986), provide the very tools needed for personal meaning-making. But we do not go as far as to argue that talk is the only feature of literacy for learning because literacy practices involve the enacted synergistic process of talking, reading and writing. It is, in fact, developed over time with a discourse community with specific characteristics of the manner we talk, read, write and think (Gee, 2014).

Edwards and Mercer (1987) dealt with the relationship between the thematic content of the lessons and the practical activities and discourse which constituted the lessons themselves. In that they identify how teachers control the teaching and learning events that occurred in a classroom to “maintain a tight definition of what became joint versions of event and joint understandings of curriculum content”; whereby the teachers framed and guided the classroom discourse to introduce and promote shared meaning and understanding of the thematic content of the lessons. Additionally Lemke (1990) indicated several “thematic development” strategies employed by science teachers maintained that how students learn to talk science through classroom discourse is a crucial part of learning science. Early studies have also show how the excessive initiate-response-evaluate (IRE) pattern of discourse led to the lack of active student engagement (Mehan, 1979) and the importance of wait time and good questioning and feedback from teachers to increase students’ thoughtfulness and opportunities for talking and learning (Chin, 2006; Walsh, 2011).
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Literacy is not simply talking, reading, or writing acting in silos, but is always being used purposefully in specific ways in a particular social context. These ways of using literacy, or *literacy practices*, are developed within a discourse community over time, and also uniquely manifested in the way we speak, read, write, think, and use various literacy tools (Alvermann, 2002; Gee, 2014; Moje & O'Brien, 2000). Informed by these perspectives, Mortimer and Scott’s discourse analytical framework is used to examine the utterances of teacher and students to analyze the dialogic and authoritative discourse. This illuminates the impacts of explicit disciplinary literacy instruction on promoting meaningful talk and sharpening the language of science in the intervention lessons.

**Methodology**

This study is carried out in Singapore. It is part of a larger 3 years period research project. This school is an all-girls’ school called Elizabeth Town Secondary School (ETSS). The students involved for this study are secondary three combined science students (grade 9) aged 15 years old with a diverse ethnic groups comprising of Chinese, Malay and Indian.

1. The Singapore education system has a streaming process that streams students into 3 education pathways after taking the high-stakes testing called the PSLE (Primary School Leaving Examination) at Primary 6 (Grade 6) – Express (E), Normal Academic (NA) and Normal Technical (NT) – when they enter Secondary 1 (Grade 7). Within the express stream, there are a further 3 categorization of (1) triple, (2) double and (3) combined sciences, where the student would learn disciplines of biology, chemistry and physics. The final year examination at secondary two would determine which category of science stream the students would be going to. The standards in setting the science categories are left to the school’s autonomy. The triple and double sciences are commonly termed as ‘pure’ sciences because the students are exposed to a denser syllabus (e.g. biology, chemistry, physics) designed for higher achieving learners, whereas for the combined sciences, although they are learning two different disciplines as well but are in the condensed form (e.g. chem/bio, chem/phy and bio/phy) for lower ability learners to better manage their learning. Despite taking two sciences, the combined science, regardless the combination, is considered as one subject whereas the ‘pure’ sciences, each discipline is taken as one subject during the high-stakes examination of the GCE O Level Singapore-Cambridge examination taken at Secondary four (Grade 10). The core differentiation is in content coverage and assessment rigor.
The class size is 27 students. The students are generally motivated with average ability according to their secondary two science final year results. Ethnographic methods were used to collect data in the classroom research. Data sources included baseline study of naturalistic classroom observation in the pre-intervention phase, teacher’s interviews, students’ work (examination papers, quizzes and worksheets, school notes) surveys, test scores, focused group discussion (4 students). Usual classroom activities included expository lectures, showing of videos and simulations, doing practice questions on worksheets; and experiments. The lessons were videotaped, in total of the baseline and intervention studies comprised of about 15 hours – pre-intervention was about 10 hours and intervention is about 5 hours thus far since the intervention phase started. The interventions were co-designed with the teacher on the topic of general waves properties (transverse and longitudinal) and sound using various strategies focusing on specific literacy skills (e.g. speaking, writing, reasoning); which differed from non-intervention lessons where fewer of these strategies were enacted as direct lecturing style is a dominant feature.

These strategies were discussed thoroughly within the research team and went through the reiterative process of refinement with the teachers. For instance, one of the strategies was to provide students a platform for engagement with activities and asking questions that facilitated discussion and sharing of ideas on a particular scientific phenomenon. The teachers have received training from 2 disciplinary literacy workshops, each was 3 hours and their perceptions of disciplinary literacy and current science teaching practices were documented in an interview by videotaping.

For this paper, we used a framework of discourse analysis for the discursive exchanges of science classrooms (Mortimer & Scott, 2003) to probe the dialogic interactions and authoritative process as communicative approaches used for meaning-making. Additionally, an in-depth study of the teacher and students’ utterances are carried out to
understand the discursive exchanges in supporting students’ learning of the scientific language. This is the basis for the subsequent micro-analysis in this study. The physics teacher, Paul (pseudonym) is a mid-career shift teacher with a bachelor’s degree in engineering and has 5 years of teaching experience in ETSS. The aim was not to be prescriptive in our approaches but provide descriptive opportunities for teachers to freely enact the strategies that they think is most appropriate as they know the students’ profiles well [students’ names used in this paper are all pseudonyms]

Findings

Findings for research question 1: What aspects of discourse approach and patterns of interaction would be considered an emphasis of disciplinary literacy instruction?

Before this question could be answered, we first need to look at the baseline study and understand how was the pre-intervention phase of the usual classroom discourse that took place in Paul’s physics class. This chapter was on light reflection and refraction whereby Paul was eliciting student understanding about the phenomenon of light rays when they reach a glass boundary as illustrated below:

Analysis

[Lesson 1, Time: 29:35]

1 T What will happen at this boundary?
2 S Refraction
3 T Refraction. OK.
4   Bend where?
5 S Towards
6 T Towards the normal.
7   Agree?
Away, away. Away. Away or towards?

Then how come they say towards and nobody say anything except for Eileen?

Anyone disagrees?

No.

Anyone not sure where or what we are talking about?

So how you decide that it is actually refraction and not total internal reflection?

It is less than critical angle.

Right.

In this episode of discourse, Paul was asking a series of questions that gave little interactional space for students to deliberate as it was leading students to an eventual outcome where the teacher already has an answer for (Wellington & Osborne, 2001). At turn 7, when Paul noticed a mistake in the student’s reply, he opened to the classroom if they agreed with her in turn 5, which was opposed by another student at turn 8. This was an example of teacher-guided-student-repair. The error correction could be guided by the teacher or initiated by the student and the error could be repaired by the teacher or the student. There are two ways that teachers could deal with error, it is either to ignore or indicate it (Van Lier, 1988). On the one hand, to ignore is to avoid error correction since it may affect the flow of discourse, on the other hand, to indicate is to correct errors so that learners acquire a proper standard of understanding. Paul decided to take the latter for most part of his teaching practice as he was checking student understanding, which was one of the means of supporting student meaning-making (Scott, 1998). At turn 15, Paul asked the question, “so how you decide that it is actually refraction and not total internal reflection?”, however the
nature of the question is so confined that the response pointed to only one possibility in turn 16, "it is less than critical angle". Again that was for checking student understanding and the same time it has a secondary role of promoting shared meaning as the responses were presented to the whole class (Table 1). However the extent of promoting shared meaning was not significant as it was merely answering Paul's questions with no explicit explanation, this could be achieved by a student who has memorized the conditions for light behavior.

In the normal deductive manner of didactic teaching of scientific principles and concepts, students' roles in class become passive receivers of scientific knowledge. Consequently, the above excerpt also highlighted the extensive use of IRE where students were responding to Paul in a rather mechanical and monotonous manner. The key finding for this account was despite making efforts in supporting student meaning-making, there was little emphasis on making the scientific knowledge accessible on the interpsychological plane either by developing the conceptual line, which included pedagogic goals directed towards shaping and selecting ideas and marking key ideas or developing the epistemological line where students are introduced to the nature of scientific knowledge such as the generalizability of scientific explanations (Scott, 1998).

In the following episode, we looked specifically at how Paul provided an explanation to a question on the same light chapter. It is reviewing a solution to a particular question that involved drawing of light ray diagrams. It is common that in reviewing a solution, the main pedagogic goal is to check student understanding. However, it did not mean there was no

[Lesson 2, Time: 31:58]

1 T They give you a light ray, P, Q, R, S.

2 From this line, is this smaller, equal or larger than critical angle? From this
one. Is this angle smaller, equal or larger than critical angle?

3 S Smaller.

4 T Right, smaller because you still have refraction.

Alright. Explain why there is no change in the direction of the ray as it enters

5 the block at Q.

6 You will find the answer right at the bottom of the page.

7 What does it say? At the bottom of the same page, what does it say?

8 S Rays are perpendicular to the surface.

9 T Ray perpendicular to the surface.

10 That is one condition. What else?

11 S They pass along the radius.

12 T They pass along the radius.

13 What does that mean?

14 You draw a tangent that would be 90 degree

15 meaning at this point your angle of incidence is how, what is your angle?

16 What is your angle of incidence at this point? What is your angle of incidence

17 of this point?

18 S Zero

19 T Zero or 90?

20 S Zero

room for exploring the explanation that entailed developing the scientific knowledge through
the use of shaping or selecting ideas and marking key ideas. In turn 5 when Paul asked for the

explanation, “why there is no change in the direction of the ray as it enters the block at Q”,

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which is an open degree of learning space. He was rather eager to help the student, Anne, in answering the question that he provided a direct support at turn 6 on where to find the answer in the notes. However a drawback with this approach was in the limited learning space and the evaluative function elicited from Paul was mainly positive affirmations of Anne’s response by repeating her answers at turn 4, 9, 12 and 20. At turn 2 and 17, the questions were guided to such a large extent; perhaps it was Paul’s intention to lead the students to the ‘right’ answer that limited the learners from the discourse interaction and their learning opportunities to express their ideas (Table 1). Additionally in turn 2 and 16, Paul repeated his own questions twice was likely due to the class response level was low, hence he would repeat questions several times to elicit responses (Tsui, 1996).

In the next part, an intervention phase classroom discourse is analysed to illustrate an episode where Paul is delivering a lesson that had disciplinary literacy strategies incorporated, which included writing scientific explanation after a simple demonstration using a slinky to represent movements of longitudinal wave particles. The class was working on an explanation question, “what do you think accounts for the movement of the compression? Explain.”. Paul has emphasised during the class that no answers would be provided and the students would need to contribute in constructing the scientific explanation together. He wanted to encourage the students to share their ideas and he would facilitate the discussion. In this discourse it involved Paul and two students, Jolie and May. From the start, Paul has utilized more referential questions (in bold) that opened the interactional space for Jolie and May to be more involved in the knowledge building and thinking process. Paul has also subtly embedded thinking scaffolds (underlined) in the form of questions to guide them in their chain of thoughts.

For this example, one would easily noticed that despite the efforts made by Paul in his questioning technique, even within a smaller group setting, the responses from Jolie and May
are short. However, it did not mean there is no meaning-making that took place. At turn 9 when May gestured with her hands movement to the right, she was referring to the slinky demonstration (Figure 1.1 and 1.2) where it represented the movements of the particles, which was affirmed at turn 11 when she completed Paul’s sentence (turn 10).

Figure 1.1 Slink demonstration on longitudinal wave motion

Figure 1.2 Student points at movement of the wave as it travels from right to left

[Lesson 3, Time: 33:16]

1  T  The motion ah. Just now this part is actually talking about motion.
2  Wave motion, particle motion. **What is their direction?**
3  OK, **at the end how you feel?** Now is **explain why do you feel it?**
4  Explain what do you think account for the movement of the compression?
5  Why do you think that this compression is actually moving?
6  **In terms of energy. The previous one how is the energy transferred?**
7  J  Err, start with the source.
8  T  Start from the source, then **what happens to the source?**
9  Then after that **what did you talk about?**
10 M  [hand gestured movement to the right]
11 T  From the source you talk about the...
12 M  Particles.
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13 T Particle that are ...
14 J (inaudible)
15 T Near to it, near to the source and then you talk about the particles that are adjacent to it and so on.
16 T That is how the energy is transferred.
17 J So how would you modify here then?
18 J Cause this one is like similar but it is not waves. I mean like not the...
19 M Not the particles going up and down.
20 J Ya
21 T Is not up and down then what direction?
22 M Is like [waving her hands left to right and back]

At the start of the question, Jolie and May seem to have no idea how to start writing the explanation. In fact, both students had problem articulating the word ‘longitudinal’ wave and had issue remembering the term ‘transverse’ which was learned before this lesson. Jolie was more comfortable with starting from the source, at a macroscopic level (e.g. a hand), this could be seen in turn 5 when Paul asked “the previous one how is the energy transferred?” which was a how question and not a where question. Instead of talking about vibration of adjacent particles, she answered in turn 6, “err, start with the source”. Paul continued to use questions to probe further in turn 7 and 8, which was responded by May. Following Paul in turn 14 and 15 used explained on how energy is transferred which was acknowledged by Jolie and May that this wave is not the same as the transverse wave. However they still could modify the explanation used for transverse waves for longitudinal wave (Figure 2).
Paul was checking student understanding and promoting shared meaning by asking questions, refocusing the discussion and also embedding thinking scaffolds to guide the students' in their responses. In this case, it was not with the whole class but within the group. He has also managed to establish continuity in the discourse from one part of the teaching narrative to the next – transverse wave to longitudinal wave. Teacher control is still visible but a lesser extent as compared to the previous two examples, where learning space was more confined. Consequently this example has also shown the aspects of *shaping ideas* to develop scientific knowledge where Paul asked a series of key questions and he allowed Jolie and May to build on their ideas from May's reply in turn 6 about starting from source and led on from there as opposed to ignoring her response and proceeding with immediate direct repair.

These findings have led us to conceptualise that the emphasis of disciplinary literacy instruction is one that focused on discourse approaches that could further enrich the learning of scientific knowledge by developing the conceptual and/or epistemological line; and in order to achieve this, the patterns of interaction should promote longer and higher quality contributions from the students. Strategies should operate at the level of joint interaction rather than disjointed solo performances to ensure the discourse flows. Evidently the disciplinary literacy instruction should also emphasize on the univocal (authoritative) and dialogic interactions not in isolation but as a continuum serving different functions of transmission of and generating meaning aspects for learning respectively (Lotman, 1988; Wertsch, 1995); as such alternation maintained the 'rhythm of the discourse' that would "enhance the learning in the classroom through achieving some kind of balance between presenting information and allowing opportunities for exploration of idea" (Scott, 1997). Hence how teachers modify their interactional resources to assist comprehension could help learners to 'navigate the discourse' through the dialogic interactions for meaning-making (Table 1).
Table 1. Analytical framework to illustrate the differences between the focus, approach and action of lessons 1, 2 and 3

<table>
<thead>
<tr>
<th>Domains of meaning-making</th>
<th>Lesson 1</th>
<th>Lesson 2</th>
<th>Lesson 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Teaching Focus</strong></td>
<td>Reviewing up a problem to understand scientific phenomenon</td>
<td>Opening up a problem to rehearse scientific concepts</td>
<td>Guiding students with science meaning and exploring students’ ideas</td>
</tr>
<tr>
<td><strong>Content</strong></td>
<td>Empirical description and explanation about light behavior</td>
<td>Theoretical explanation about light behavior at a glass boundary</td>
<td>Empirical description and theoretical explanation about waves</td>
</tr>
<tr>
<td><strong>Communicative approach</strong></td>
<td><strong>Interactive / Authoritative</strong></td>
<td><strong>Interactive / Authoritative</strong></td>
<td><strong>Interactive / Dialogic</strong></td>
</tr>
<tr>
<td><strong>Patterns of interaction</strong></td>
<td>Triadic IRE</td>
<td>Triadic IRE</td>
<td>IRF-RF-RF-(RE)-IRF-</td>
</tr>
<tr>
<td><strong>Action</strong></td>
<td>Checking student understanding and promoting shared meaning</td>
<td>Checking student understanding and reviewing</td>
<td>Shaping ideas, checking student understanding and promoting shared meaning</td>
</tr>
</tbody>
</table>
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Findings for research question 2: How does discourse approach and patterns of interaction foster meaning-making and sharpen the specialized language used?

Our key findings are that the dialogic process for meaning-making allowed students to bring together and work on ideas that developed in conjunction with the increasing specificity of the language used. In so doing, the discursive exchanges orchestrated by the teacher have explicitly supported students’ ability to accurately describe a scientific concept (e.g., the wave motion) from a physics viewpoint.

Analysis

[Lesson 4, Time: 42:27]

OK. So that you are saying that the big wave will become small wave and stable.

1 T Alright anything else? OK. Any feedback, comment? No? Mary? What did you all discuss?

2 M The particles don’t move sideways, they move up and down.

Particles don't move sideways, they move up and down. When you talk about

3 T particles, what particles are you talking about?

4 M The particles in the water

The particles in the water, are you talking about water molecules? So you are saying

5 T water molecules, particles is nothing wrong, I just want to be more specific. Ya.

6 A The ball is not moving because… (inaudible)

7 T The ball is not moving because the particles in the liquid are... (inaudible)

8 A (inaudible) …the particles are, the water molecules that are moving is balanced.

In this episode, after a video was showed to the students, they were given a few questions to discuss on the topic of general wave properties exploring transverse waves. The
video showed a ball floating on the surface of the paper and did not move from its position despite an ongoing wave produced moving from right to left – 1) the water appears to be moving from right to left. If so why does the ball remain stationary on the surface of the water? and 2) what is moving in a wave motion and in what direction?

In turn 1, the teacher, Paul was paraphrasing Allison’s reply in the previous turn that is not shown in this excerpt. From her response, Allison was giving an empirical description of the observable phenomenon from the video. Subsequently, when he asked for Mary’s comments, she provided a theoretical description which is beyond the phenomenon involving “particles” (turn 2) describing theoretical entities. Paul then wanted to be more specific in the scientific language and probed for what “particles” referred to in turn 3. Following in turn 4, Mary articulated “particles in the water”, which Paul reiterated as “water molecules”. For this instance, Paul allowed Mary to express her own ideas and offered specificity of terms used in turn 5. It was interesting then in the next turn 6, where Allison decided to refine her understanding spontaneously. In turn 8, Allison used “particles” which she did not earlier and followed quickly by a self-initiated self-repair correction by rephrasing as “water molecules”. With this revision, Allison is also providing a more theoretical description beyond just the observable phenomenon of the ball and water.

In turn 12, when Paul asked for Kristine’s input, she seemed to have adopted Allison’s voice as she expressed her ideas with similar utterances “water molecules balanced” (Bakhtin, 1986). Consequently, she like Allison has performed a self-initiated self-repair correction as indicated by “the wave molecules, the water molecules”. Paul then probed further (turn 13) and in the subsequent turns that indicated Kristine had issues expressing her ideas coherently (turn 14 and 16), perhaps due to the lack of language specificity and terminologies at this early stage of introducing the topic.
It is like the, *what is that call ah?* The wave molecules, the **water molecules** balanced.

13  T  Balanced, meaning?

14  K  It’s like when **one is up, then the other is down.**

15  T  So when water molecule is balanced when one is up, the other one is down.

16  K  So it is like **pushing, so it stay there.**

17  T  So it's pushing what?

Causes one is up and one is down, the wave is here right? Then it like it goes

18  K  here. So like.

*More like a see-saw is it?* Like a see-saw, is that what you are saying. So she's

19  T  saying that it is more like a see-saw, when one is moving up, one is moving down, so it would just be just rocking left and right.

Paul realized that Kristine was struggling with expressing her ideas using scientific terms, hence he used the analogy of a see-saw gaining from a collection of her ideas from turns 12, 14 and 16 (bold words). Paul seemed to be engaged in a non-interactive dialogic process within himself as he took the voice of the Kristine into consideration to make sense of what she was trying to express when he probed further in turns 13, 15 and 17 (Bakhtin, 1986). From this episode, there are two important assertions made:

1. Through the dialogic process for meaning-making, ideas are brought together and worked on, and these ideas are jointly refined in conjunction with the increasing specificity of the language used by the students. As highlighted previously, the use of “*particles*” in turn 3 to “*water molecules*” in turn 12 and the self-initiated self-repair by Allison in turn 8. This is important as it delineates the *ball as the object that is*
carried and water molecules as the carrier. Such a distinction would then help to understand the word “balanced” in this instance as articulated in turns 8 and 12. As the water surface around the ball are alternating up and down (turn 14) – similar to a see-saw motion as one party goes up, the other comes down – this “balanced” motion results in the ball not moving along sideways with the wave, but just bobbing up and down in the same position on the water, in turn 16 “so it [ball] stay there”.

2. The discursive exchanges orchestrated by the teacher have explicitly supported students’ ability to accurately describe the wave motion from a physics viewpoint. Paul facilitated more specific terms to describe the phenomenon in turn 5. Additionally the change in description by the students from an empirical account to a more theoretical one has emerged in the dialogic process after Mary’s utterance in turn 2. Although description change was not initiated by Paul, it was however, propagated by him in the subsequent discussion from turn 3 with further open-ended referential questions than close-ended display questions.

Using Mortimer and Scott’s discourse analysis illustrated in the table 2 below. In this episode of talk, the teaching focus was to open up a problem in this case about the ball and water using a more dialogic discourse to develop students’ views using the IRF exchange interactions (Sinclair & Coulthard, 1975) to probe and share students’ ideas at the same time refining the use of language. It is important to take note the type of questioning technique used in this episode where the teacher has utilized a series of referential questions that promoted more interactional responses as opposed to the usual display questions that is mostly seen in the didactic teaching that yielded simple responses. The types of questions have different functions in a classroom discourse, neither one is more superior to the other, but how they are used skillfully in the class is a crucial move of achieving the desired pedagogic goals.
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<table>
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<tr>
<th>Teaching Focus</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Empirical and theoretical descriptions of the wave motion and the movement of particles by experiment</td>
</tr>
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<table>
<thead>
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<th>Approach</th>
<th>Action</th>
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<tbody>
<tr>
<td>Communicative approach</td>
<td>I-R-F-R-F chain (without teacher’s evaluation)</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patterns of interaction</td>
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</tbody>
</table>

**Table 2. Analysis of lesson 4 interactional space and discourse**

In this next episode of discourse regarding sound and the using of the formula \( v = f \lambda \) to answer a multiple choice question. Paul used a more authoritative approach here but still interactive because he felt a need to reinforce the concept in providing a scientific explanation. Although it is a multiple choice question, how a student derived the answer involved reasoning skills that could also be very complex and needed to be addressed and shared with the class. In turn 2, Suriyana provided a simple response relating to the formula, however in turn 3, Paul explicitly mentioned that “you start off with equation”. Following in the turn 4, Suriyana was rather specific in the language she used “directly proportional and if frequency is constant”. Paul, in turn 5 highlighted the focus by reiterating her response to the class “you have to state ah, what is constant. Frequency is constant”. Finally in the turn 6 of Suriyana’s utterance of “how to have the longest wavelength, the speed must be the fastest”, Paul concluded that with the “cause and effect” statement establishing the relationship between a physical phenomenon and scientific concepts.
Then question 7. How do you arrive at answer D? If you are to explain, it is a
qualitative question, you have to explain how do you do it

Just say wavelength is speed over the frequency

Ok you **start off with equation**, and then

So speed is *directly proportional* to wavelength, if the frequency is constant

(...)

Uh **so you have to state ah, what is constant.** Frequency is constant, then

How to have the (longest) wavelength, the speed must be the fastest

So when the (cause) speed is fastest, the wavelength will be the longest Ok,

Your constant, **your cause, your effect.**

So it's D.

Alright? So you get D. Ok with that reasoning?

[class applauded for the pupil who just answered and laughed]

In this scenario, the meaning-making process is not as prominent as the previous
example, but you can see how the teacher explicitly frames the dialogic process for meaning-
making to help other students and emphasizing on specialized language to navigate the
discourse that would make sense to them; which was positively recognized by the class at the
end. Consequently central to Vygotsky’s sociocultural theory of learning is the idea of
conceptual knowledge first occurs between people on the interpsychological social plane and
then internalized at the intrapsychological individual plane. It is therefore important to note
that Paul has somewhat explicitly injected a structure through his talk as a form of
scaffolding the students’ meaning-making and thinking process. In so doing, students first understand Suriyana on the social plane and their internalization has reinforced their learning on the individual plane through the scaffold that helps frame their thinking.

Here, the communicative approach is *interactive authoritative* where Suriyana proactively answered Paul’s elicitation of explaining a multiple-choice question using a formula. Teaching focus is very much opening up a problem and guiding the students with science meaning. Through Paul’s method of framing Suriyana’s explanation, he provides scaffolding for students’ thinking process; which would allow students to internalize the conceptual knowledge. Concurrently, he also emphasized on the scientific terms used by Suriyana focusing on the key words and providing the theoretical explanation of the phenomenon, this allows the students to understand from the social plane to an individual plane of knowledge transfer. Hence it was noted that teacher’s univocal talk was an important form of scaffolding the students’ meaning-making and thinking process (Table 3).

<table>
<thead>
<tr>
<th>Focus</th>
<th>Teaching Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>Focusing on the key words and explanation by using the formula that provides a theoretical explanation</td>
</tr>
<tr>
<td>Approach</td>
<td>Communicative approach</td>
</tr>
<tr>
<td>Action</td>
<td>Patterns of interaction</td>
</tr>
<tr>
<td></td>
<td>Triadic IRE</td>
</tr>
<tr>
<td></td>
<td>Forms of intervention</td>
</tr>
<tr>
<td></td>
<td>Reviewing, marking key ideas, checking student’s understanding and sharpening scientific language</td>
</tr>
</tbody>
</table>

Table 3. Analysis of lesson 5 interactional space and discourse
Disciplinary Literacy and Meaningful Discourse

Discussion, implications and limitations

Learning science is not solely an isolated act of interpreting information and providing explanation from tested hypotheses. Within a classroom structure, it is also about social interaction and dynamic engagement with ideas amongst peers. School is a place of socialization where language is used pervasively to make sense of the talk around all its participants and as a tool in classroom, it is used in discourse for collective thinking, as mentioned in Mercer (2000) "when working together, we do not only interact, we interthink". Therefore I will address two areas of concerns in the current situation of teaching science practice in the local context and also highlight some of the implications.

Firstly when science is taught excessively in a didactic manner, it could limit the learners from talking as a social practice to share ideas, explore the nature of science and joint construction of scientific knowledge. This could then encapsulate them in into a shell of passive learning and knowing about science that restricts their ability to master the scientific language and to use it effectively (Mercer, 1995). As one of the student, Kristine has expressed during the focus group discussion that comprised of four students:

"Umm, yes, because like I don’t know, like what term to use, and like, cos, there’s like all the energy involved and stuff, then I don’t know how to phrase it."

Grounded upon the sociocultural perspective of learning where talk is an important aspect of meaning-making to students such as Allison who articulated what she felt when she could actively participate in scientific discourse during physics lessons:

"It’s needed, because what you think may not be the same as what other people think, so you can actually learn from other people’s explanation of certain stuff. so, yeah, it gives you a better understand of the different ways people will put together their understanding of certain stuff.”
These sentiments illuminated the need for learners to immerse in meaningful discourse by sharing ideas and rehearsing scientific concepts through the skillful orchestration of the teacher to make the discourse more communicative and improve the interactive decision-making to create opportunities of learning. The implication would possibly be the extent of causing them to depart from their lesson plan and take up more time and resources than expected. Some salient questions science teachers need to reflect upon and ask are to what extent is the discourse including or excluding learners from the interaction? What types of questions should be asked and how are they answered? How appropriate is the language used to achieve the pedagogic goals?

Secondly, skills of higher-order thinking such as scientific reasoning, argumentation and critiquing is commonly missed out in our classroom learning culture (Wong & Lau, 2014). From observing the class after a period of time, the students show hesitation to actively participate in classroom talk during lesson and appeals to be a rather reticence class when it comes to discussion and sharing ideas openly even after much probing from the teacher. This could be a common feature in Singapore’s classrooms as students are generally more reserved and may not explicitly show their enthusiasm in coming forth with answering questions and sharing ideas. Although these various forms of scientific discourse may not be spontaneously displayed by students, it could be facilitated by the teachers in promoting such talk with the strategies used in the disciplinary literacy instruction as a mean of learning to do and talk science in new ways.

The implication is efforts may be needed to first engage the students so they would feel comfortable in talking (a shift in classroom culture and students’ learning behavior) using different conceptual tools and communication modes. For instance, one of the strategies was to help students visualize abstract theoretical entities such as wave particles by using a hands-on rope experiment activity. It was used in conjunction with writing descriptions and
Disciplinary Literacy and Meaningful Discourse

explanations to allow student to engage in disciplinary literacy skills such as talking and writing. The rope represented the medium and the demarcated colour tapes represented the wave particles (Figure 3.1 and 3.2). It was an effective enactment of this strategy as illustrated by Yolanda regarding the writing and talking aspect of the activity (Appendix 1),

"Err very effective, because, not like he's [Paul] just feeding us the answers, but we have to understand."

Figure 3.1 Rope experiment with demarcated colour tapes
Figure 3.2 Teacher demonstrating the direction of wave motion and particles movement

and Kristine expressed what if the activity was not used:

"I would not understand it at all. Because, like, umm, the diagram just tells me how the wave moves, but then, umm, we don't really like, we won't really understand how it works unless we actually try it out."

More attention should be focused on developing the scientific knowledge by shaping and marking ideas that provides through dialogic interactions for meaning-making in scientific discourse as a result using the sharpened language in writing and talking. However, an important notion that is commonly misunderstood is that effective teacher talk does not mean less teacher talk (Cazden, 2001; Mercer, 1995; Walsh, 2011), similarly hands-on experiments and group work does not automatically meant student-centric pedagogy grounded in the practice of disciplinary literacy instruction. It is the emphasis of teacher modelling scientific explanation and engaging students in scientific discourse with activities
used in the context of the talk that integrates specialized literacy skills of the discipline in content area, which could so often be missing in science classrooms. Therefore the implication would be teachers would need to consider a more inductive method of teaching science that explores the scientific phenomenon, getting students to ask scientifically oriented questions, gathering evidence to justify a claim, generating and testing hypotheses and make reasonable explanations; as opposed to the traditional deductive method of teaching science with lesser opportunities of discourse in formulating hypotheses and creating explanations to justify claims because principles and laws are seen as ‘ready-made’ material waiting to be transmitted from teacher to student in an univocal mode.

Limitations

One limitation is about the generalizability of each respondent’s utterance to the other students. Much of the data is collected from a whole class discourse setting. However at any moment, it is 1 – 2 student(s) responding. Therefore, the individuals’ utterances that were collectively extended to the class as a whole may not be representative of every learner being able to internalize and make meaning of the concepts addressed. Second limitation of this study on classroom discourse, is that the interpretation and analysis was based on verbal data as a predominant indicator of interactional function could only be inferential at best. The methodological issue was raised by Barnes and Todd (1977, 1995). Third limitation is the large class size and learning culture where students’ responses are limited and non-elaborative, it was difficult to retrieve spontaneous talk. Additionally due to the nature of combined science stream, the requirement for the students to present extensive written scientific explanation is low. The resultant need for scientific discourse to negotiate meaning is therefore limited as well. This inevitably impacts on the learning approach of science which demands more time for the learners to accustom to the ‘new’ scientific discourse.
Conclusion

This study contributes to the understanding of how the disciplinary literacy teaching strategies in the intervention lessons that incorporated specific literacy skills of reading, talking and writing have promoted a more dialogic interaction among participants leading to meaningful classroom talk. As Wertsch (1997) suggests that “whenever we speak we must ‘buy into’ an existing set of linguistics terms and categories.” In so doing, students are able to actively participate in classroom discussion with the specialized language that is enacted and sharpened through the discourse. The research also informs literacy instruction and teaching strategies that teachers could employ to improve discursive interactions and explore the basis of how teacher’s talk could be an important form of scaffolding the students’ meaning-making and thinking process. Consequently, Scott (1998) postulates that “in learning to talk science we must ‘buy into’ and learn to work with the conceptual tools, epistemological framing, ontological perspectives and forms of reasoning of the scientific community.” It is clear that ‘learning to talk science’ is a more complex issue than simply using terminologies but extends to questioning, reasoning and explaining in the joint construction of knowledge, which would require more research work in this area of disciplinary literacy.

ACKNOWLEDGEMENTS

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References


Scott, P. (1997). *Teaching and learning science concepts in the classroom: talking a path from spontaneous to scientific knowledge*. Paper presented at the an international seminar held at Universidade Federal de Minas Gerais, Belo Horizonte, Brazil.


[Lesson 3. Time: 33:16]

T The motion ah. Just now this part is actually talking about motion.

Wave motion, particle motion. What is their direction?

OK. at the end how you feel? Now is explain why do you feel it?

Explain what do you think account for the movement of the compression?

Why do you think that this compression is actually moving?

In terms of energy. The previous one how is the energy transferred?

J Err. start with the source. Source is at a macroscopic level

T Start from the source, then what happens to the source?

Then after that what did you talk about?

M [hand gestured movement to the right]

T From the source you talk about the...

M Particles. Translating to discuss at a sub-microscopic level

T Particle that are …

J (inaudible)

Near to it, near to the source and then you talk about the particles that are

T adjacent to it and so on.

That is how the energy is transferred.

So how would you modify here then?

J Cause this one is like similar but it is not waves. I mean like not the...

M Not the particles going up and down. Differentiating from transverse waves

J Ya

T Is not up and down then what direction?

M Is like [waving her hands left to right and back] Longitudinal waves
Practice question

Explain how energy is transferred in a ripple produced by dropping a pebble into a pond in terms of the motion of the water particle. Use the diagrams provided below to explain your answer.

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. KE</td>
<td>Kinetic energy moves to D. The kinetic energy of the particle D is transferred to the water particles by a ripple wave.</td>
</tr>
<tr>
<td>2. A B C D E F G</td>
<td>The motion of particle D moves up and down in a wave-like pattern. The wave causes the adjacent particles to move up and down.</td>
</tr>
<tr>
<td>3. A B C D E F G</td>
<td>D begins to vibrate. The energy is transferred to the particles adjacent to D, causing them to vibrate.</td>
</tr>
<tr>
<td>4. A B C D E F G</td>
<td>Because of the vibration, the other particles around it move around by well. The water particles vibrate up and down.</td>
</tr>
<tr>
<td>5. A B C D E F G</td>
<td>The direction of transfer of kinetic energy is now transferred to the rest of the particles. The transfer of KE from water particle D to the adjacent wave particles.</td>
</tr>
</tbody>
</table>

Helpful keywords:
- Kinetic energy
- Adjacent
- Transfer
- Vibrate / vibration
- Motion of particles
- Maximum displacement