Structuring of Reasoning Process in Scientific Explanation through a Multimodal Classroom Discourse

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Abstract

It is recognised that the nature of talk between teachers and students is highly significant that seeks to assist students in the learning, reasoning and knowledge building. The ability of student to generate a sound explanation is a hallmark of meaningful understanding and is definitely one of the desirable skills specific to Science discipline. While multimodality is inherent in science classroom teaching and learning, much attention has been drawn to how the range of different modes make meaning beyond language in classroom teaching. However, not much research was done to understand how science teachers structure the reasoning process in a scientific explanation through the use of multimodality. In this paper, reasoning process refers to the deliberative thinking that involves consideration of science content knowledge or contextual information to construct the canonical scientific explanation for a question. Video data of classroom teaching of a Physics teacher in a secondary school was analysed to investigate how the teacher structure the conceptual understanding and the reasoning process required to construct scientific explanation. Through a multimodal analysis and micro-discursive analysis of the teacher-led discussion, it was found that the modelling of the reasoning process was implicitly embedded in two common practices: (i) sequential translation of multiple representations and (ii) using discursive techniques to link up the rhetorical parts of the explanation. Based on the findings, future possibilities and suggestions of connecting multimodality to reasoning skills for both research and practice are discussed.

1. Introduction

With a growing recognition that learning science concept entails understanding and conceptually linking different forms of representations, various studies were done on how multiple representations could be used more effectively to construct new knowledge in science education (Prain & Waldrip, 2006; Tang, Tan, & Yeo, 2011; Tytler & Hubber, 2010). Despite the long standing characterisation of some aspects of multimodality in science teaching, and despite recent characterisation of multimodality in constructing representations to learn science, the question of "what develops" from representations in terms of logical reasoning have not been thoroughly addressed. While constructing this logical sequences predominant in all science explanation, many students struggled to relate their claim to specific science principles when writing a scientific explanation (Sandoval & Millwood, 2010).
To address the gaps, this paper focuses on analysing the teacher-led discussion within a physics classroom in Singapore using lens informed by multimodality framework and disciplinary literacy theory. The purpose of this study was to find out how multiple representations could be used as a tool in physics classroom teaching and modelling of reasoning skills that is required to construct a scientific acceptable explanation. As such, our research question guiding the study was: How is scientific reasoning skills taught in the physics classroom?

2. Literature Review & Theoretical Framework

"Multiple" representation in science education refers to the practice of re-representing the same concept is another form (e.g., verbal, graphic, and numerical modes) (Prain & Waldrip, 2006) while "multi-modal" refers to integration of different modes to represent findings, explanation or a science process (Tytler, Prain, & Peterson, 2007). Our research is informed in part by the theory of social semiotics (Lemke, 1990), which posits that language (e.g., speech, writing) and all other symbol systems (e.g., images, gestures) function as meaning making resources for people to make different meaning in any social context. The mode of speech in the form of classroom interaction have been well researched which includes Mehan's (Mehan, 1979) work of I-R-E (initiate-response-evaluate) interaction sequences of most classroom discourse and other areas of classroom talk (Mercer, 2010; Wells, 1999) for learning. It is important to take into consideration the concept of modal affordance which originates from the work of Gibson (Gibson, 1977). This concept describes what is possible to easily represent and express in a mode. A particular mode could better express a kind of meaning than another mode when explaining science.

In the discipline of Science, students are often required to state and explain a particular phenomenon. A causal explanation usually consist of three components which include (i) phenomenon identification or stating what is known,(ii) temporal or causal sequences and, (iii) the stating of outcome (Veel, 1997). This explanation structure is generalized as Premise-Reason-Outcome (P-R-O) for the analysis in this paper. Writing a canonical scientific explanation requires the disciplinary literacy to use the specialized language and multimodal representation of the discipline (Moje, 2007).

3. Research Context

The data analyzed for this paper is taken from a three-year design research project that aims to develop disciplinary literacy instruction in science with two secondary schools in Singapore. The research project consists of two phases, with the first phase involving one-year baseline observation of the existing disciplinary instructional practices within the teachers' content area instruction. The subsequent phase is an intervention study which involved the design of the presumptively more explicit disciplinary instruction to be embedded in the same classrooms observed during the first phase.

This paper report findings that focuses on the video data collected from a physics classroom teaching session during the second phase of the project. A sequence of classroom activities and activity sheets were co-designed between the researchers and teacher on the topic on *Forces* to embed more explicit disciplinary literacy instruction specific to writing scientific explanation for a phenomenon observed.

4. Analytical Design

A broad analysis which was informed by a multimodality analytical framework (Tang, Delgado, & Moje, 2014) was used to examine how the role of multiple and multimodal representations in reasoning process involved in that particular selected case. Selective coding was used to examine the types of information (i.e. scientific principle, observation, contextual information, causal sequence of events and conclusion or outcome to be explained) in the classroom discourse from episodes that involved teacher explaining a particular science concept or phenomenon. In this paper, we would also present how each representation contributes to the reasoning process to construct an explanation, through the micro-genetic analysis of the teacher-led discussion.

5. Findings

One episode from the lessons was selected to illustrate the connections between the different representations and the embeded reasoning moves. This episode is not presented as an exemplary episode, but to seek to foreground how reasoning process could relates to the distinct nature of the meaning-making representational resources.Through a micro-genetic analysis of the teacher-led classroom discussion, we mapped each of the reasoning process during the whole-class discussion to each representation used.

At the start of the teaching sequence, students were to discuss and state their prediction in an activity sheet which involved a few scenarios. Next, students observed a particular demonstration. After the observation, students wrote down the observation and explanation concerning their observation for the phenomena using drawings and annotations. This is repeated for 2 other scenarios. Finally, the teacher did a whole class discussion to established Newton's third law and modelled the structuring of the explanation.

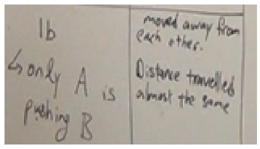
Segment 1 illustrates the demonstration for one of the scenarios where one student pushed the other student on the back when both of them were standing on a skateboard.

Segment 1: Observation & Exploration

Speaker	Utterance & Non-verbal Actions	Logical Process	Representation
T	Okay, he is the one doing the pushing. So observe the push okay.	Observes phenomena	 *Image 1*
T	So this is what happens. On the next page, fill up what you see. What happens, why happens and your explanation again.	-	

In *segment 2*, the teacher did an observation probe in the first 3 shaded episodes which are code as *contextual information*. *Image 2 from table 2* shows the written account consolidated from the students for the observation of scenario 1b. The purpose of this episode was to recall the observation of the *opposite direction of the reaction force* when a force is exerted on a body as seen from the written form "moved away from each other" and "distance travelled almost the same". This segment contributes to the structuring of the outcome for a science explanation.

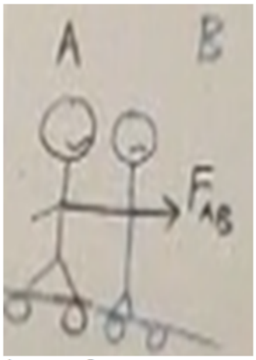
Segment 2: Recall Observation

Speaker	Utterance & Non-verbal Actions	Logical Process	Representation
T	*And then* when we move on to 1b, where only Shawn is **pushing** Zac.	States observation	 *Image 2*
T	When Shawn is **pushing** Zac right, what is the **observation**?	*Probes for outcome*	
S	Both of them **move** back	States outcome	
T	Again they **move away** from each other.	States outcome	

Next, the teacher proceeds to re-represent the 2 students using stickman diagram. In this segment, the observation of the scenario was re-considered and translated into stickman diagram (image 3). Here we could also see a progression of language used, from everyday langauge "Shawn is *pushing* Zac" to a more scientific language where Shawn "*exerts* a force on Zac". Then, the teacher get the students to hypothesize the underlying cause for why A (Shawn) moved backward. The stickman diagram used in this segment is associated to hypothesis making of the reasoning process which contributes to the structuring of the reason for an explanation.

In segment 4, the same stickman diagram was used to make connection between the observation and the underlying physics concepts. Annotations and arrows of different colour was added to the stickman diagram to illustrate the different direction of the forces that were acting on the skaters. Through the use of the diagram, verbal and gestural interchage between teacher and students, connection was made between the phenomenon observed and Newton's third law. In this segment, the diagram is associated with the connection making of the reasoning process which contrbutes to the structuring of the 'Reason' for the explanation. Finally, the teacher proceeds to using P-R-O strategy to model the structuring of explanation on the whiteboard illustrated in *table 1*.

Segment 3: Making hypothesis

Speaker	Utterance & Non-verbal Actions	Logical Process	Representation
T	*I have Shawn here, always with a weird smile.*[Drawing stickman]	Re-represent	 *Image 3*
T	*He* ***exerts*** *a* ***force*** *on Zac...*	States observation	
T	*So, A, let's call it A , A easier…and B*	Re-represent	
T	*I am using black colour to represent the force from Shawn.*	Re-represent	
T	*Okay, this makes sense. So the force is acting on B.*	States a cause	
T	*That's why B moved forward.*	States outcome	
T	*Then* ***why did A move backward*** *according to you all?*	*Probes for cause*	
S	Recoil…Like a gun	*Proposes a cause*	

Segment 4: Making Connection

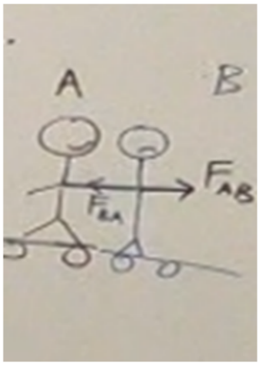
Speaker	Utterance & Non-verbal Actions	Logical Process	Representation
T	Opposite, yah, blue color **force** acting backwards like this.	Sates cause	
T	Eh, I write this AB ***<u>because</u>*** the **force** comes from A acting on B.	*Expands*	
T	And from this one, ***<u>because</u>*** the moment they have contact like what you have observed or you have say there will **an equal and opposite reaction force** that is from B onto?	*Expands*	
S	A		
T	A..***<u>So</u>*** they are **acting** on different body. One force is on B, one force is on A.	*Expands*	

Table 1: *Teacher modelling the crafting of scientific explanation*

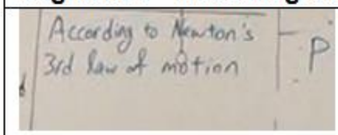
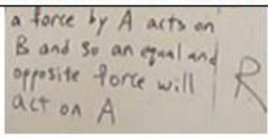
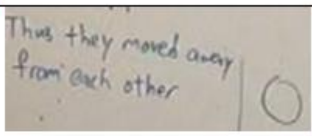
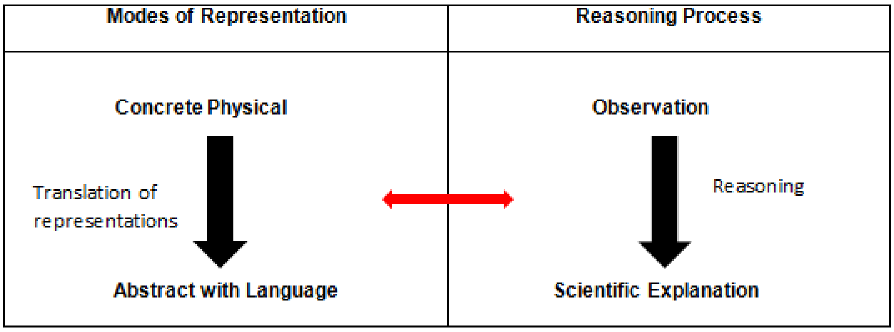
Segment 5 – Modelling using Premise-Reason-Outcome strategy		
		

Table 2 below illustrates generalisation on the relation between modes of representations and reasoning process when a concrete physical phenomenon is translated to more abstract specialised language of the discipline. As such, our key assertion is that classroom modelling of reasoning process could be implicitly embedded in sequential translation of multiple representations.

Other than the use of diagram, the verbal interchange between the teacher and students play a pivotal role in linking the different segments of reasoning components together. As such, it is argued that the modelling of the reasoning process is embedded in sequential translation of multiple representations (verbal, graphic, and numerical modes etc.) and also the discursive techniques such as I-R-E interaction that link up the different components that are necessary to construct the scientific explanation.

Table 2: *Generalisation on relation between representations and reasoning process*



6. Conclusion

In conclusion, this study sheds light on how reasoning process could be implicitly embedded in the translation of representations and discursive techniques to facilitate the crafting of scientific explanation. The pedagogical implications of the assertions align with Vygotskyan views of learning, that language and thought come together and are combined as cognitive tool for the learning process in students. The findings suggest that learning science entails the capacity to integrate and link different representations to construct the conceptual understanding. This also aligns with various researches done on the use of multiple representations in learning science. Explicit structuring of reasoning process is certainly a desirable trait that goes beyond the outcome of a typical science curriculum. Further research could be done to investigate how this modelling of reasoning process to craft the science explanation could be better imparted to the students.

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