Methodological framing of comparative video analysis of reasoning in science classrooms

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The Equalprime project uses classroom video capture to compare teacher support of reasoning in primary science classrooms in Taiwan, Germany and Australia. Originally there was some expectation that the analysis would involve agreed coding schema that would allow quantitative comparisons of the teachers, but the reality is that more context specific and targeted qualitative analyses are proving more defensible, in conjunction with some quantitative context codes. The paper will discuss the validity of different methodological approaches related to the complexity of the reasoning construct and of classroom negotiation of reasoning. We question the validity of coding based on singular models of reasoning, and argue for a case study approach drawing on multiple analyses, driven by an emergent, context-rich narrative.

Introduction

'Equalprime' is a cross national study of Grade 3/4 primary science classrooms in Taiwan, Germany and Australia. The aim of the research is investigate teaching and learning practices that create opportunities for quality reasoning and learning in science. A key focus is the culturally based factors that shape these practices.

Studies of student reasoning in science have involved a variety of types of data collection and analysis, including laboratory studies probing students' capacity to reason in co-variation situations (Koslowski, 1996), interview studies probing students' coordination of ideas with evidence (Driver et al, 1996; Tytler & Peterson, 2003), and studies of reasoning from video records of classroom. These latter studies have involved analysis of student and teacher talk, focusing for instance on the use of evidence in argumentation (Furtak, Hardy & Beinbrech, 2010), on teacher and student coordination of multi-modal representations (Hackling, Murcia & Ibrahim-Didi), or on student representation construction and talk (Prain & Tytler, 2012). In this latter study, we argued that reasoning through visual images is an important aspect of science knowledge building (Gooding 2006). We have also argued, following Ford and Forman (2006) and Manz (2012), that current formulations of argumentation as

the basis for knowledge building in science fails to capture the contextual problem solving and collaborative representation construction and transformation (Latour, 1999) that characterizes scientific epistemic processes. Argumentation is best seen as set within a context of searching for solutions to problems that are highly contextual and contingent (Manz, 2012) and involve idea generation based on both formal and informal reasoning (Gooding, 2006).

Given this recognition that scientific epistemic processes, and associated reasoning, are fundamentally contextual, contingent, complex, and multi-modal, we have come, in the Equalprime project, to the position that formal coding schemes based on argumentation, or any other structured schema, will inevitably fail to adequately capture reasoning across the range of situations and topics that comprise the study. Identifying evidence to support claims is a very narrow perspective on knowledge producing processes in science. Each such schema will be at best partial, and comparative analyses across cultures and topics, based on such single measures, will be of limited validity. Our question, for this paper, is: 'What data generation and analysis processes are needed to build a valid account of teacher support of reasoning in Grade 4 science classrooms, across topics and across cultures?' and 'what should be the methodological framing of such studies?'

Method

The teachers involved in the project have been identified by peers as representing quality practice in science teaching and learning. Each teaches a sequence of lessons on a substantive science topic, which is videotaped for shared analysis. The Equalprime team has developed a set of protocols to govern the collection and sharing of video data. The data generation involves two cameras, one on the teacher and another on a group of students whose learning is to be studies. In some cases a third camera, of the whole class, is used. Video records are constructed for each lesson in a topic sequence. Other data includes student artifact collection, teacher resources, interviews with teachers and students at two or more points in the sequence, field notes, and data concerning the school and school population. Information is also generated concerning school structures and traditions, the education system, and public attitudes to education.

Three sample lessons from each sequence are prepared for sharing across the group, with transcription and where necessary translation into English. Detailed descriptions of the whole sequence, with activities and resource descriptions, are also generated and shared. A time-coded analysis of classroom organization – whole class, small group or individual work – is also provided for each sequence.

The Victorian team is using Studiocode software to organize the data and perform a variety of analyses. The international team has agreed that any analysis and writing that involves another country's data must involve members of the team from that country. Thus, the particular insights of any country's team concerning the cultural or other backdrops to the data are brought to bear on the analysis.

This paper will discuss complexities of the analysis of reasoning across classes in the three countries, including by way of example comparative analyses of three teachers involved in the study: 1. Bob, from Australia, a specialist science teacher teaching a unit on Force, 2. Mrs H, from Taipei, also a specialist teacher, teaching a

unit on the moon and its phases, and 3. Mr A and Mrs L, who co-taught a unit on levers in the KM school in Germany. No claims are made about the representativeness of these teachers of their countries, and discussion of cultural factors is not a feature of this paper. Rather, they will be taken as classes with differences in the way reasoning is thought of and supported in primary school science.

Analysis

Analyses of formal and informal modes of reasoning in a previous project (Tytler et al., in press) generated a definition of reasoning as *deliberative thinking that involves choices, leading to a justifiable claim*. This broad definition will drive the analyses presented in this paper.

In the project teachers focused on one of four broad topics, so some justifiable comparisons could be made. However, in the current analysis even within the topic of *force* the focus is quite different, so that the thinking required is not equivalent. In the astronomy unit the reasoning centrally involves spatial relations, and models play an explicit and major part. In Bob's forces sequence there are many investigative activities that involve choices of apparatus, choices of measurement approaches, and identification of underlying factors affecting flight or movement generally. The KM school sequence was based broadly on problem solving and involved a variety of strategies such as student constructed design/modeling investigations, and classroom forums identifying central features of the problem. In all sequences however the task was to generate explanations of phenomena, at each stage with supporting evidence. The evidence was, however, of a variety of types. It is thus clear that a single account of reasoning that does not acknowledge these diverse approaches to *deliberative thinking that involves choices, leading to a justifiable claim,* cannot lead to valid comparisons of reasoning across cultural settings, let alone across topics. We have thus been challenged to develop a broader reasoning framework, and associated methodological approach, to allow such comparisons of support for reasoning.

This paper describes an approach to identifying and comparing support for reasoning that involves a diversity of types of analysis, reflecting diverse forms of reasoning and support for reasoning, driven by an emergent comparative narrative. Each analysis is based on a short, 10-15 minute classroom discussion / activity sequence in which the teachers moved the students towards a particular scientific explanatory idea. The analyses involved

1. A discourse analysis that identified the particular ways the teacher moved students towards a more scientific understanding, focusing on the broad structural outline of the strategic direction
2. An analysis of patterns of teacher request for claims and backing of claims
3. An analysis of the different patterns of ways in which these teachers responded to and worked with students' input
4. An analysis of the different semiotic tools with which the reasoning proceeded.

These will be reported in turn. In each of the sections, methodological issues associated with the reasoning category are discussed.

Broad patterns of support for reasoning

Bob's sequence

Bob's sequence involves students coming to an understanding of the role of air in determining the speed of fall of objects – in this case a sheet of paper. The sequence includes a whole class sequence built around a demonstration of the fall of a scrunched up piece of paper to a flat piece, then moves to students working in groups to explore ideas, then to a whole class discussion in which various ideas are canvassed, evaluated and refined. The structure of the sequence can be seen through Mortimer and Scott's (2003) distinction between dialogic and authoritative discourse. In dialogic discourse, students are invited to suggest ideas, which are not evaluated. The conversation is open and student voice accepted. In authoritative discourse the teacher uses a variety of processes to channel thinking, with more control of student input and more evaluation, either implicit or explicit.

Phase 1: exploring the phenomenon and establishing ideas. After establishing that scrunching the paper makes it fall faster Bob asks why. There are three explanations a) It's heavier, b) there is less distance, and c) there is more force (Bob: where does the force come from? Scrunched up)

There is then a group investigative activity. Bob circulates and collects ideas, again not evaluating but asking for clarification. He gets four responses:

- The folded paper falls faster (Bob: why?) .. because it's thicker
- It cuts through the air (Bob: 'hold onto that')
- It takes up space, air pushes up (Bob: what does the air pushing up do?) … makes it slower.
- It's aerodynamic (Bob: what's that?) … air goes round easier. Air resistance.

Phase 2: whole class review of explanations - a process of selective refinement. This is the authoritative phase where Bob gradually works with the ideas to achieve some resolution. In this, he:

- establishes some of the ideas that came up in group discussions.
- emphasizes the explanation based on air being trapped under the open paper causing a slower fall
- elicits from one student the important idea of area
- introduces the idea that thickness is an alternative explanation which allows him to directly explore whether area or thickness is the relevant variable

Having established area as the most convincing factor, he then introduces the possibility of weight being a factor for the open and folded paper. By a process of open contributions and emphasis he establishes that area 'catching the air' is a better explanation and the weight is the same – convincing one girl who originally believed it to be different.

Bob works in a non-evaluative way, questioning and demonstrating, emphasizing and selecting responses first to establish student ideas as part of the conceptual territory he will work with, and then in the final class discussion orchestrates these to establish the plausibility of the air flow/area view rather than the counter –

explanatory ideas of thickness and weight. He can do this by carefully selecting the task (same bit of paper, narrowly focused activity) and anticipating the likely views that students will come up with. Monitoring and clarifying views are central to this practice.

The support for reasoning in this sequence involves a process of continual challenge to students to predict and explain quite focused demonstrations and tasks, and the careful sequencing of the discussion to ensure all ideas are in the open and then gradually evaluated and refined. In this process, Bob is assiduously non evaluative in his response to student input, but challenges continually, requesting claims and backing, involving clarification, elaboration, or justification through evidence.

Mrs H's moon phase class

The sequence analysed involved the teacher working with a projected image of a half moon, establishing which is the east and west side and the track of the moon across the sky. At first students assume that the left hand side of the image in west, transposing normal N-S-E-W directions onto the image. Mrs Hong accepts this but by asking for alternative opinions and working with these in a non judgmental way, she moves the students to realise that because the image is seen in the southern part of the sky, then the directions are reversed from their expectation.

In this excerpt the focus is on spatial thinking/reasoning – getting students to orient themselves with respect to the moon and the moon's motion and orientation with respect to the southern horizon and east and west.

Mrs H. was very patient in not contradicting all the class but kept asking for ideas and asking for backing, using a students' argument that we looking at the moon in the south to sow seeds of doubt, accepting a number of counter proposals, and finally resolving the issue by displaying another figure of the moon's path E-W across the horizon, at the same time as holding a photograph of the third quarter moon, so that students re-thought their orientation in space. Finally she clarified the point they had come to, and added some explanation of the motion of the earth from West to East to explain the moon's motion in the sky. In the sequence Mrs H:

- constantly requests claims and backing
- alternates between checking the thinking of individuals and the whole class
- regularly invites students to contribute other ideas
- doesn't allow easy answers to go unchallenged.
- has a commitment to resolution of the ideas and pushes for that.

As with Bob, she supports reasoning through constant requests for claims and backing, and is non-evaluative in the way she deals with student input. The reasoning of students is not as apparent in that most of the responses are 'yes' or 'no' and she often asks for votes on explanation options she presents as dichotomous.

Mrs L and Mr. A's lever class at KM school

The lesson sequence started with speculative interpretation of a workman's gondola suspended using counter weights from a tall building. Students put forward

ideas about 'what was happening' and over a series of lessons they interpreted this in terms of physical attributes and lever principles. In the excerpt studied here the students had previously modeled the situation using a cradle with weights, sticks and counterbalances, exploring the relation between suspended weight, counterbalance, and physical arrangement. The teachers had placed photographs of each of the student designs on the board, and the discussion concerned "If one wants to build as stable a construction as possible one needs to pay attention to ……"

The task itself had been designed so that questions of weight and placement would emerge and the aim of the discussion was to clarify the relation between these, in broad terms. The teachers worked by selection of the task and then the photos they put up, and further by the emphasis they gave to various responses. They gradually moved students to talk about the position of the counterweights and why they should be at the ends of the poles, and also the importance of the distance from the edge to the weights either side.

The student responses were mostly speculative and quite detailed, compared to Bob's class and particularly Mrs. H's. The question was never put dichotomously. The prodding and selecting is more subtle and gentle than in either of the other cases. The argumentation framework of claim/backing doesn't really capture the model based reasoning and speculation / explanation going on in this sequence. The claims are varied and can be put into different categories: conceptual claims, claims about patterns, claims about what is important to notice …

To summarise the commonalities and differences between these three teachers' support of reasoning, some key characteristics can be identified. First, the teachers continually invited students to make claims, to back these claims with argument, linking with other ideas, or with evidence. The nature of the reasoning was different, varying from model based (Mrs H), reasoning through experimentation to establish factors (Bob) or interpret the important elements of a physical set up (KM teachers). The teachers did not operate with the traditional IRE pattern, never being directly evaluative but rather operating more subtly in their responses to achieve consensus around an idea. The student responses were of a very different quality, ranging from mainly short responses, yes-no (Mrs H) to short explanations and speculation (Bob), to longer more elaborative speculative explanations (KM school). All three teachers used student voice to constantly monitor ideas, and strategically input questions or responses that moved students by degrees towards scientific interpretations.

Teacher response to student input: claims, elaboration, evidence

Each teacher consistently invited and challenged student ideas, asking for justification and evidence and encouraging extension of their thinking. This is consistent with an argumentation framework but was broader than the narrow claim/backing/evidence often associated with this. They differed in the extent to which they requested claims and backing, and the manner in which this was done. The nature of the claims requested was quite varied as discussed above. The manner of request for backing was also varied. An analysis was carried out using studiocode, analyzing the way the teachers challenged student responses, scaffolding students' reasoning as 'deliberative thinking that involves choices, leading to a justifiable claim'. The coding categories for 'teacher response to student input' included: request

for clarification, request for elaboration, implicit or explicit challenge to the idea, re-voicing (sometimes extending), and direct evaluation. Results from a studiocode analysis of the patterns of these responses showed considerable individual variation in the patterns of response, and in the relative weighting of teacher and student 'talk time'. These patterns reflect differences in teachers' pedagogical beliefs, but are also related to particularities of the topic and task. The interpretation thus cannot stand alone but needs to draw on aspects of the context.

The nature of evidence provided by students to support their claims was also very varied, from direct reference to phenomena or data sets, to argumentation using analogy, to appeals to reason through theoretical ideas. Thus, the argumentation framework, because of the many different ways in which each element appears in the discourse, does not allow a valid comparison of these teachers, across these topics. Their practice in support of reasoning is varied, eluding capture by a single analysis framework.

Identifying reasoning

Another difference between these teachers is the extent of overt, extended student reasoning occurring in the excerpt. In the KM case the student responses were often quite extended and this was encouraged by teacher silence or the nature of the challenge. In the Taipei case the student input was mainly very brief, occurring in response to challenges that often asked for a choice between dichotomous options. In this case the evidence for reasoning is in the nature of the choice in response to the challenge. What we are seeing is not explicit displays of reasoning in this case but rather evidence through choice of response – can the students reason in this case to produce a valid answer?

Thus, there is variation in the manner in which teachers elicit student reasoning: at the one end of the variation students are encouraged and supported to produce elaborated and explicit reasoning moves (KM case); at the other end (Mrs H's class) their opportunities to reason publicly are constrained, but the reasoning can be surmised by the quality of their short answers to teacher posed dichotomous questions. Bob's case lies in between these.

Semiotic tools to support reasoning

Reasoning by its nature always draws on a variety of tools, including verbal language, visual language in the form of diagrams or animations, mathematical representations, and gestural language. Mrs H drew on multiple visual representations – projected onto a whiteboard – of moon phases and moon trajectories, coordinated with labels and further photographs. Students thus reasoned through these multiple visual tools, and their arguments referred to these as well as gestures (pointing, turning) in developing explanation or solving problems. In Mrs H's class generally she made use of many visual representations sourced through the students' textbook and accompanying CD, as well as internet images.

In Bob's case there were almost no visual representations displayed. Nevertheless there was a rich language developed through artifact and gesture which supported students' reasoning – pointing to features of the paper, emphasizing the importance of height of dropping by mime, and strategically displaying aspects of the paper shape.

In this case the reasoning drew significantly on artifacts and processes as well as embodied representation.

In the KM classroom sequence the teachers drew on the photographs to emphasise certain features of the design principles, and students in constructing speculative explanations also pointed carefully to features in the displayed experimental arrangements.

In each of these cases the reasoning cannot be understood through the words alone, but involves thinking through visual, spatial and embodied modes. The video record is crucial for understanding the nature of the reasoning – the claims and the backing, and the analysis and synthesis of pertinent aspects of the visual record.

Discussion/Conclusion

In this section I will first point to substantive aspects of the findings – the commonalities and differences between the ways these teachers supported reasoning. Second, and drawing on this analysis, I will discuss the possibility of a valid comparison of the level and mechanism for supporting student reasoning across these cases.

There were a number of commonalities between the teachers:

- The teachers are non evaluative. They encourage open dialogue and ideas. This is a matter of explicit principle for the KM teachers but also for Mrs H who lets students persist with a wrong view for quite some time and gradually finds a way to challenge them. In no case was the classic IRE pattern followed.
- In each case there was a constant request for claims but the nature of the claims varied considerably. In Mrs H's class the claims emphasized spatial orientation. In KM the claims were about identifying patterns and generating analogies with levers. In Bob's case the claims were quite varied – from observation, to hypothesis and prediction, to explanation, to inductive interpretation of patterns.
- Each teacher found ways to work with students' responses to move them forward, but the types of pattern used were varied. Strategies had features in common, for instance feeding responses back to the class, requests for further ideas or of elaboration, were used by all. The selection of responses to highlight productive direction, the repeat of significant responses as markers, and the pointing out of contradictory positions, were all used.

The differences in the three teachers' practice include:

- The degree of scripting of the task and endpoint
- The extent to which science ideas are explicitly introduced by the teacher
- The degree of prompting and selecting of responses to move students forward – more open or more closed

- The length of student responses and therefore the overtness of the reasoning and explanatory moves. This was quite short in Mrs H's class and quite extended in KM.
- The nature of the representations – either canonical (Mrs H) or constructed by students (KM) or restricted to verbal, gestural and artifact use (Bob).
- The pace was very different and also the patterns of class organization.

From this analysis it becomes clear that reasoning is not a unitary entity, there are many facets of reasoning in science classrooms. Drawing a valid comparison based on coding involving quantitative counts becomes a problem because of the highly contextual nature of the reasoning. The numbers would also be misleading in that they are not generalizable, given the non-representative nature of the sample. However, constructing case studies of these teachers' practice, based on an emergent narrative of comparison, allows the generation of insights into difference and commonality in support for reasoning. Analyzing the practice of these culturally disparate teachers in a variety of ways – ethnographic analysis, quantitative coding, identification of themes – provides a framework through which to view reasoning and strategies to support it. The identification of constant points within this variety can allow us to see the core elements of pedagogies supporting reasoning, that transcend culture.

Just as we argued that formal argumentation patterns were best seen as lying within complex, contextual and contingent problem solving approaches, we argue that formal and informal discourse analyses of classroom video data are best viewed as part of the construction of a narrative concerning teachers' practice in supporting reasoning, that acknowledges the complex and contingent nature of quality science teaching and learning.

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