

Video Analysis of Physics Teachers' Explanatory Frameworks

David Geelan

Department of Secondary Education, 341 Education South, University of Alberta, Edmonton AB T6G2G5, Canada.

dgeelan@ualberta.ca

Abstract

The ways teachers explain ideas to their students are an important part of teaching and learning physics. They are also related to the context of the physics course, and to the personal style of the teacher. This study used qualitative analysis of videotaped classroom teaching from 15 high school classrooms in a Canadian urban setting, complemented by surveys and videotaped interviews with teachers and students, to attempt to capture something of the richness and complexity of teachers' explanatory frameworks. The close, comparative analysis of classroom video was considered valuable both as a piece of research into teaching and as a way of developing a resource for communicating richly the practices of teacher explanation to teacher education students. The explanations were generally of a high quality, but the factors of context and personal style meant that each teacher's explanatory style was to some extent unique. Features of high quality explanations in physics were identified.

Introduction

How do good, successful physics teachers explain the core ideas of physics to their students? Do they do it through lecturing, through leading discussion, through almost incidental comments when discussing the results of laboratory sessions? Do they discuss the nature of science explicitly, or is it implicit in the way they describe physics concepts? What distinguishes good, clear explanations that lead to deeper understanding on the part of students from explanations that lead to alienation or incomprehension? An earlier study that a group of colleagues and I conducted in Perth, Western Australia (Geelan, Wildy, Loudon & Wallace, in press (a), in press (b)) drew my attention to issues around teacher explanations. Each of the four teachers whose teaching was videotaped and analyzed in that study had a very different personal style, and was teaching in a very different context, so their practices were very different. Yet each of those teachers had a history of excellent results on external final examinations, and was judged to be teaching and explaining ideas in excellent ways.

In the present study, teachers in six high schools in an urban Western Canadian context were invited to participate in the research project. The schools were chosen on the basis of their results in the external Diploma Examinations in physics in the preceding five years, and each of the six schools had achieved very good results. The intention of the study was to try to capture and analyze the teaching practices of excellent, highly successful (in simple, achievement-test forms, but with an eye toward more complex forms of excellence related to teacher-student relationships and deep student understanding) physics teachers. The intention was both to try to understand – in rich, complex, context-sensitive ways – what it is about good explanations that makes them good, and to be able to use video vignettes in combination with the understandings developed in the course of the research to be able to show these features of excellent explanations to students in teacher preparation programs.

Explanatory Frameworks

Science teachers' explanatory frameworks – the way they use analogy, metaphor, examples, axioms and concepts, and the way these elements are tied together into a coherent whole – are an increasing focus of interest in science education research (Treagust & Harrison, 1999, 2000; an ERIC search on 'physics' and 'explan*' yields 864 hits, including too many recent and highly relevant papers to include in the space available here). This work is related to more than one of the dimensions of teacher expertise identified by Hattie (with a number of collaborators) (Bond, Smith, Baker & Hattie, 2000; Hattie, Clinton, Thompson, & Schmidt-Davis, 1995, 1996). The nexus of the discussions in science education about explanatory frameworks with those in education more generally about teacher expertise, combined with the new analytical tools made available by video analysis, provide an area for research that is potentially highly fruitful in delivering rich understanding of what constitutes excellence in physics instruction. Such understandings in turn have the potential to be fruitfully introduced into the pedagogy of science teacher education, including the use of actual classroom video in prompting prospective teachers' critical reflection on issues related to expertise in science teaching.

Treagust and Harrison (2000) discuss the issue of explanations in science and science teaching. They note that secondary school students often confuse explanation with description (Horwood, 1988), and draw on Ruben's (1990, 1993) work on the philosophy of explanations to discuss issues around explanatory frameworks. They note that:

There are important philosophical and epistemological differences between science explanations and science teaching explanations. Science explanations are strictly characterized as theory and evidence-driven, use the correct scientific terms and include analogical models. Science teaching explanations differ in rigour, length and detail, involve varying degrees of 'explain how' and 'explain why', are sometimes open-ended, include human agency and can raise new questions as they answer previous questions. (p. 1158)

Strasser (1988) draws a distinction between 'explanation', which he identifies as the mode of the natural sciences, and 'understanding', which he identifies with the 'human sciences', hermeneutics and phenomenology. This distinction is useful in discussing the differences between science explanations, which are law-like, highly generalized and rigidly logical, and science teaching explanations, which can be more fluid, and can draw on analogy, anthropomorphism and teleology in order to connect with students' prior understandings and life contexts.

Treagust and Harrison (2000) discuss Richard Feynman's (1994) lecture 'Atoms in motion' as an exemplar of excellent explanations in physics teaching, and describe a number of characteristics of explanatory frameworks. They note that there is some controversy among philosophers over whether an explanation is a product – a thing unto itself that can be abstracted from its context and still be meaningful – or whether an explanation must include the process of explaining *to* someone. It seems to me that context is very important in assessing the quality of explanations, particularly those given with a pedagogical intent: to give a trivial example, an explanation of physical quantities and processes that is appropriate for my 8 year old daughter would not be appropriate in a 3rd year university physics course, but it might be the perfect explanation for her right now. Treagust and Harrison (2000) divide explanations into three broad classes: scientific content explanations, effective pedagogical content explanations and everyday explanations. Scientific explanations deal in laws and law-like relationships, statistics and strict inductive or deductive logic. Pedagogical content (Shulman, 1986, 1987) explanations are those given by teachers to students, and can be anthropomorphic, teleological, and use analogy and metaphor. Everyday explanations tend to be more intuitive and vague, and can draw on anecdotal evidence and idiosyncratic theories.

The following features of science teaching explanations are identified by Treagust and Harrison (2000) in their analysis of Feynman's (1994) lecture:

- analogies and metaphors, including anthropomorphisms and teleological explanations;
- careful qualification of analogies and attention to places in which the analogies break down or no longer usefully map onto the target concept;
- use of axioms of physics, accompanied by explicit attention to the evidence from experience and experiment that supports those axioms;
- development of physics concepts and their elucidation through carefully chosen examples;
- dynamic use of both imagination and reason (logic) in explanation; and
- development within the listener of a 'dynamic and fluid mental model'.

The discussion of the teaching practices of a number of teachers later in this paper draws on these elements of explanatory frameworks in science.

Research Methods

As indicated above, the research approach chosen uses multiple methods of both collecting and interpreting the research data (Geelan & Hopkins, in press). Schools within the Edmonton Public School Board (separate and private schools may be included in a later extension of the research project) were chosen on the basis of their highly successful physics results in the external diploma examinations, published on the Alberta Learning web site. The principals of selected schools were contacted, and permission sought to contact the Head of Department of science and the physics teachers in the school, in order to seek their participation in the study. Where teachers agreed, between 3 and 5 hours of videotape were recorded in their physics classrooms. Each teacher was recorded with one class group. Teachers, parents and students were also surveyed on issues related to teacher explanations and

expertise, teachers interviewed, and focus groups of 56 students participated in discussion of the issues around teacher explanations. These focus group discussions were audiotaped and transcribed for analysis. The collected video footage was transcribed, and analyzed for explanatory frameworks and pedagogical strategies using vPrism, a software package that allows parallel coding and analysis of the video and the transcript.

Results

The explanations conducted by the teachers involved in the study included most of the features identified by Treagust and Harrison (2000), though in differing proportions depending upon the individual teacher's personal style, and on the context (type of school, type of student group, class size, content area being covered, time of the school year (i.e. in introduction of new topics for the first time or in revision close to examinations)).

Analogies

Teachers used analogies very regularly in their classes, as a way of making bridges for students from their existing knowledge to new concepts. Some teachers were very careful in delineating the 'likes and unlikes' of analogies – features that were and were not shared by the target concept and the source concept – while other teachers used analogies in ways that occasionally confused students because the teachers did not pay careful attention to unwarranted inferences from analogies. Analogies observed included those between water waves and light waves, and between light moving from one medium to another and a car moving from pavement to a muddy surface.

Axioms

Teachers used axioms of physics such as Newton's Laws, and in some cases provided students with empirical evidence (in experiments and demonstrations) to support these axioms. In other cases the laws and relationships of physics were largely taught as 'received knowledge', based on the authority of the teacher or the text, or on the requirements of 'what you have to know for the exam'. While the latter strategy may be necessary in some cases to allow teachers to 'cover the syllabus', or because empirical evidence for some axioms may be difficult to obtain in the classroom, teachers who paid explicit attention to the *kind* of evidence that would be necessary and sufficient to establish an axiom generally created clearer explanations, and developed an understanding of the nature of science on the part of their students.

Conceptual Development

The teachers in the study did tend to attend explicitly to the ways in which students developed particular concepts of physics, and particularly to the logical links between concepts, or to the 'structure of the discipline'. This occurred to a greater extent *within* particular topics or units than *between* topics, although where links occurred between topics many teachers did refer students back to concepts from earlier units, or foreshadow concepts from units to be studied in future. Teachers also attended to the development in students of individual concepts and of networks of related concepts, but the emphasis on linking concepts together varied widely between teachers: some apparently expected students to make these connections on their own, spontaneously, while other teachers paid very explicit attention to students' understanding of how physics concepts relate to one another.

Imagination and Reason

Teachers shifted easily between enlisting students' reason and their imagination. Imagination was drawn on particularly to envisage either physics-related things that have happened in the students' prior experience or experiments recently completed as a class, but also to imagine situations such as a world free of friction or gravity, or to imagine phenomena such as the wave/particle duality of light that cannot be directly observed. Teachers made comments such as 'in this situation, imagine that light is a wave – how would it behave? How would it behave differently if it is a particle?' Teachers also drew on students' reasoning, asking them for the logical consequences of axioms and laws of physics for particular situations. Teachers tended not to explicitly teach logical reasoning in physics, but to assume that students reasoned in accordance with the laws of logic. Even in situations where a student's wrong answer was due to a logical flaw, the teacher was more likely to re-explain the physics concept involved than to tend explicitly to the logical problem. As was observed with analogies, some teachers spoke

explicitly about the shifts between imagination and reason, while for other teachers such shifts were implicit – just part of the on-going story of physics in these classrooms.

Mental Models

Students tend to develop mental models with or without the explicit attention of teachers to this facet of their learning, but when teachers did describe their own mental models and ways of understanding the phenomena, students reported being more aware of their *own* mental models, and of making more use of mental modeling in their thinking about physical problems. Mental models are related, although different in kind, to analogies – they are simplified, but rich and fluid, mental representations of either the structure of a particular concept or of ‘what will happen’ in a particular physical situation, rather than comparisons between the concept and some more familiar situation.

Conclusion

The use of classroom videotapes, combined with a qualitative analysis software package such as vPrism, has the potential to allow researchers to analyze in detail the fast-moving practices of classroom teachers, the professional judgments that inform those practices from moment to moment (Griffiths and Tann (1992) refer to such judgments as ‘reflection in action’), and the explanatory frameworks that help teachers to increase students’ understanding of difficult concepts. By drawing attention to, and providing concrete, context-sensitive, authentic examples of such explanatory frameworks and their use in the classroom, such videotapes and the associated understandings also have the potential to enrich teacher education, through giving preparing teachers access to the strategies and approaches of experienced teachers.

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