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RESEARCH REPORT

Effectiveness of a Classroom Chemistry Demonstration using the Cognitive Conflict Strategy

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In an action research study, 66 students from Year 11 in an Australian school were shown the colour of methyl violet indicator in some hydrochloric acid solutions, and then in an acetic acid solution. The intent was to create a cognitive conflict, resolution of which would lead to an understanding of the concept *weak acid*. Student learning emanating from the demonstration was evaluated by written answers to the following: 'Describe the demonstration', 'What was the aim of the demonstration?', 'Explain the observations', and 'What do you think you have learned?' Some students were also interviewed. Learning outcomes were disappointing, not because of failure to resolve the intended conflict, but because of failure to attend to the key features of the demonstration and failure to realize a conflict. Some interesting cases of unintended, and undesirable, learning occurred. The role of the teacher was a focus of this study, and recommendations to improve the conduct of cognitive conflict demonstrations were implemented in follow-up years, and improved learning outcomes resulted.

Introduction

The main characteristic of demonstrations based on the cognitive conflict strategy is that the observation is contrary to the students' expectations, in the light of their prior knowledge. Its basis is that resolution of the disharmony will result in meaningful understanding. Appleton (1993, p. 1) describes a discrepant event as a 'puzzling situation which is counter-intuitive'. The discrepancy between expectation and observation is often brought into sharp focus by asking students to predict what will happen before the demonstration is conducted. This strategy is consistent with the predict–observe–explain method of probing understanding described by White and Gunstone (1992).

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The labels *conceptual conflict*, *cognitive dissonance*, and *discrepant event* are used interchangeably with *cognitive conflict*.

There has been considerable theoretical consideration of the cognitive conflict strategy, whether associated with classroom demonstrations or not, from an epistemological perspective (Dreyfus, Jungwirth, & Elizovitch, 1990; Hewson & Hewson, 1984; Nussbaum & Novick, 1982; Rowell & Dawson, 1985; Smith, Blakeslee, & Anderson, 1993). A useful critical review has been provided by Fensham and Kass (1988), and Limon (2001) has published an appraisal of past research findings, although generally not in the context of classroom demonstrations, with discussion of the factors that may be important in successful use of the cognitive conflict approach.

Conceptual Change

There is strong evidence that students' conceptions are resistant to change (Driver, 1989; Duit & Treagust, 1998; Osborne & Freyburg, 1985). Demonstrations with a cognitive conflict strategy are sometimes used to encourage students to engage in conceptual change. This strategy has been endowed with a sense of validity by Posner, Strike, Hewson, and Gertzog (1982) and by Strike and Posner (1985), who proposed four conditions necessary for conceptual change: dissatisfaction, intelligibility, plausibility, and fruitfulness of the intended outcome.

Somewhat consistent with these conditions, Pines and West (1986) have defined the phases of 'conceptual exchange' arising out of cognitive conflict situations as awareness, disequilibrium, and reformulation. White (1994) believes that current classroom practice concentrates on the intelligibility and plausibility conditions, but overlooks the conditions of creating dissatisfaction with existing beliefs and convincing learners that the new notion is fruitful.

Obviously, the conflict resolution process is critical. Ineffective resolution may leave the student with unintended or inappropriate interpretations, or in a state of confusion. There is evidence (Gunstone, 1991) that students may even resolve conflict by modification of the observation rather than of his/her understanding. Mitchell (1992) provides an example of a physics lesson that illustrates the recognition and resolution of conceptual conflict through class debate.

Although there are advocates of the opinion that a sufficient aim of conflict resolution is construction of meaning that is viable for the student, we are firmly of the view expressed by Fensham, Gunstone, & White (1994, p. 36) that '… construction [of personal meaning from experience] does not give students licence to claim that their meaning is as good as scientists' meaning, no matter what its form. Construction does not mean "anything goes"; some meanings are better than others'. We are in accord with the view expressed by White (1994, p. 120) that 'the classroom debate has to be managed so that the scientists' view wins'.

The research described in this paper set out to investigate whether the scientists' explanations of observed phenomena 'won' in lessons that were based on chemistry demonstrations presented with a cognitive conflict strategy by a teacher. It further attempted to provide insight into the factors that either enhanced or inhibited achievement of the intended learning outcomes.

Context of the Research

The research was conducted in real settings at the Year 11 level in a private secondary school for boys in Perth, Australia. One of the authors (M.B.) was the teacher of these classes, and she was engaged in action research (Carr & Kemmis, 1986; Kember & Kelly, 1993; Mills, 2000) in the sense that reflection upon the findings concerning the effectiveness of presentation of a chemical phenomenon led to modification of later presentations, which were also studied.

The purpose of the demonstration under study was to develop an understanding that only a small fraction of molecules of some acids (called *weak acids*) ionize in aqueous solution. It has been reported that students find this concept difficult or counter-intuitive (Oversby, 2000; Rayner-Canham, 1994; Ross & Munby, 1991).

Three Year 11 classes, one in each of three successive years, were involved in the study. Class 11/1 had 22 students whose abilities were, in the judgement of the teacher/researcher, mostly in the average to above-average range. Class 11/2 had a wide range of abilities over the 23 students, mostly of above-average ability. Class 11/3 contained 21 students mostly of low to average ability.

The Demonstration

The purpose of the demonstration was to develop the understanding that when some acids are dissolved in water, only a small percentage of the acid molecules ionize. A further intended outcome was that acids that behave in this way are called *weak acids*.

Acetic acid was used as the weak acid exemplar. The basic procedure is summarized as follows:

- Hydrochloric acid solutions with concentrations 1 M, 0.1 M, 0.01 M, and 0.001 M were made up in front of the class by successive dilutions from the 1 M solution, and samples of each were put into Petri dishes.
- Methyl violet indicator was added to each solution, producing the colours yellow, green, blue, and purple, respectively.
- A 1 M solution of acetic acid was added to a fifth Petri dish and the students were asked to predict what colour the methyl violet indicator would go when added. The indicator was added and observed to go blue—different from that in the 1 M hydrochloric acid solution, and about the same as in the 0.01 M hydrochloric acid solution.

The manner of the presentation was intended to enhance the likelihood of the surprise that the indicator was not yellow in the 1 M acetic acid solution. Each presentation began with an introductory discussion to set the scene. Follow-up discussions were used to give students the opportunity to develop acceptable explanations for the observation in a group setting.

None of the Year 11 classes involved in the study had received prior instruction about the difference between strong and weak acids.

Methodology

Each presentation, including the discussions before and after, was video-taped and the audio track was transcribed.

After the presentation, all students were asked to respond, in writing, to the following: 'Describe the demonstration', 'What was the aim of the demonstration?', 'Explain the observations', and 'What do you think you have learned?' The effectiveness of the presentation was evaluated by analysis of the students' responses to assess: whether they knew what had been done procedurally; whether they appreciated why the teacher had conducted the demonstration, from a chemistry perspective; whether they made appropriate inferences and constructed sensible understandings from the observed phenomena; and whether they perceived any advance in their chemistry knowledge. In some senses this analysis mirrors an assessment scale of Radford, Ramsey, and Deese (1995), who used demonstrations to assess students' scientific understandings and process skills, except that the current study included the metacognitive components contained in the second and fourth assessments above.

In addition, in each year three students were interviewed after the demonstration to probe their understanding of what had happened, using stimulated recall techniques (Marland, 1984; O'Brien, 1993). The students who were asked to volunteer for the interviews were chosen to represent different ability levels within their classes. All of the students asked to participate did so. These interviews were usually conducted within 2 or 3 days of the presentation.

In the light of analysis of students' responses concerning the effectiveness of the demonstration, and reflection upon video replays of the presentations, judgements were made about how the presentation could be improved. Consistent with the principles of action research (Carr & Kemmis, 1986; Kember & Kelly, 1993; Mills, 2000), the demonstration was then presented to classes in the following years, in each successive case in a manner modified in the light of previous findings. While the chemical phenomena demonstrated were the same from class to class, modifications included students' prior knowledge (through modification of what was presented in classes leading up to the demonstration), the manner in which the purpose of the demonstration was expressed, the quantity and quality of what was said prior to, during, and immediately after the presentation, what was written on the board, the labelling of the solutions, and even the dramatic style of the presentation.

In deciding how to modify each successive presentation, and how to interpret the research findings concerning each, the researchers needed to take into account the experience and abilities of the students in each class. This is a highly subjective process, depending very much on the skills and knowledge of the teacher.

Contexts, Findings and Discussion

Class 11/1: Context

In the five lessons preceding the demonstration, the teacher had discussed definitions and properties of acids and bases, and the self-ionization of water, and had introduced the concept of pH. Although the concept of ionization of acids in water had been presented, the notion of incomplete ionization of some acids had not. These students had not experienced cognitive conflict demonstrations before.

During the demonstration, the students were gathered around the laboratory bench on which the experiment was conducted. When indicator was added to the hydrochloric acid solutions, the teacher related the indicator colour to the pH of the solutions (rather than the concentrations of H^+ ions). While the teacher referred to the names of the acids and the concentrations of the solutions, these were not written on the board or the Petri dishes. The formulas of hydrochloric acid and acetic acid were not given, since the teacher assumed these were known.

No explicit statement of the aim was made; the teacher introduced the demonstration with the broad statement 'I want to look at some different acids in more detail.'

Class 11/1: Findings

Of the 22 students in the class, 18 predicted that the indicator would turn yellow in the 1 M acetic acid. This was to be expected, since the students did not know that acetic acid ionizes to a lesser degree than hydrochloric acid. The other four students predicted different colours because they felt they were being 'tricked', rather than for reasons of chemical logic.

The findings were disappointing. Five students made no mention of the acetic acid solution. Of the 17 students who did refer to the acetic acid solution, six did not specify its concentration. Most students went beyond procedural descriptions and included some reference to the purpose of the demonstration. Fifteen students' descriptions focused on the relationship between indicator colour and either pH or hydrogen ion concentration. Those students who referred to pH showed that their understanding of the concept of pH was inadequate. None of the students referred to the hydrogen ion concentrations in any of the solutions.

Only one student stated an aim that loosely corresponded with that intended:

> The aim of the experiment is to see the ionization of different acids. The experiment showed it well if you only know how to read the results.

Almost all students seemed to have missed the point of the demonstration, many deciding that it was an investigation of either the hydrochloric acid solutions or the indicator:

> The aim of this experiment was to dilute HCl and test acidity and pH levels in different concentrations.

> The aim of this experiment was to find what colour the various acid concentrations went and the relationship of the colour and the pH.

The significance of the difference between the colours of the indicator in the 1 M acetic acid and hydrochloric acid solutions was, in general, not appreciated. Of three students interviewed, the following extract characterizes the perceptions of two of them:

> … to show how the concentration of…hydronium ions in solution affected pH value.

One student, in their written response, was brutally honest:

> The aim was to completely confuse us. It worked.

In their written attempts to explain the observations, none of the students related indicator colour directly to hydrogen ion concentration. With hindsight, perhaps this is not surprising since the teacher had not done this either. As a consequence, none was able to compare the hydrogen ion concentration in the 1 M acetic acid solution with that in the 1 M hydrochloric acid solution.

After watching a video replay of the lesson, two of the three students interviewed correctly deduced that the concentration of the hydrogen ions in the solution of the weak acid was less than in the hydrochloric acid solution of similar concentration. However, despite participation in a post-demonstration discussion and further lessons, both students incorrectly suggested that the reason was related to the different number of hydrogen ions in molecules of the two acids:

> Um, there's less … hydrogen parts on the empirical formula [of the acetic acid]. Has that got something to do with it?

> … you get more hydrogen out of a metal sort of thing, um, … if you poured say hydrochloric acid in than lemon juice or something which is a weak acid.

Class 11/1: Discussion

The evidence indicates several important deficiencies of learning outcomes that were achieved during the demonstration. A number of the deficiencies relate to the dissatisfaction condition for conceptual change (Strike & Posner, 1985).

First, although the colours of the indicator in the various hydrochloric acid solutions were intended to be merely the vehicle used to create the cognitive conflict, some students thought that these colours constituted the essence of the demonstration. These students could not have experienced the intended conflict. Secondly, for the 50% of students who did not know, or did not realize the significance of, the concentration of the acetic acid solution, achievement of the intended learning outcome was not possible. Thirdly, hardly any students appreciated the difference between the two 1 M acid solutions in terms of different hydrogen ion concentrations, and so it is difficult to imagine how most students could have effectively engaged in the intended conflict resolution process.

Obviously, an important teaching skill is the ability to focus the students' attention on the key features of the demonstration so that the cognitive conflict is recognized. Presumably the students who did not refer to the acetic acid in their descriptions did not recognize its significance. White (1991) reports similar evidence in relation to a ninth-grade class who were taught about the gas laws through the agency of a demonstration with a large cylinder and plunger. The next day, about one-third of the class did not remember having seen the apparatus. Consistent with the information-processing model described by Johnstone (1997), White points out that the first step in the processing of an event is the selection for attention of its key features from all of the sensory signals that we receive. Surprisingly, it seems that when students make observations that are inconsistent with their predictions, they do not necessarily experience dissatisfaction. We conclude that the teacher needs to be explicit, if not repetitive, and perhaps even dramatic, in directing the students' attention to the potential conflict.

It became evident that the intended conflict was only accessible indirectly; inferences can be made about the pH values of the two solutions from the observed indicator colours in the two 1 M acid solutions, and then it is necessary to make further inferences about the relative hydrogen ion concentrations. The teacher frequently related the indicator colour to pH rather than to hydrogen ion concentration, even though the concept of pH had only been introduced in the previous lesson. The students' understandings of the pH concept were poor, and this almost certainly interfered with their sense-making. It would have been more straightforward to draw a correspondence between the colours of the acid solutions with H^+ concentrations, rather than with pH values.

Although the teacher appreciated the importance of adequate prior knowledge, perhaps it is easy to underestimate the period of time need for interaction with, and reflection upon, conceptual knowledge before it becomes useful.

The most obvious deficiency of the demonstration was the students' inability to identify an aim close to that expected by the teacher. This evidence is of some concern, because Gunstone (1991) has pointed out the importance for students to be aware of the aim of a practical activity. Again, perhaps, there is a need for the teacher to be explicit and emphatic. However, there is an obvious tension between clarifying the aim of a cognitive conflict demonstration to students and maintaining the counter-intuitive nature of the presentation. If this demonstration were to be used to illustrate a previously taught weak acid concept, the teacher would be comfortable with an explicit statement such as 'I will now demonstrate to you that only a fraction of the acetic acid molecules in solution ionize.' However, this statement of aim would be inappropriate when the intention is that students construct this meaning via conflict resolution.

It was not surprising in hindsight that many students seemed unable to specify the names and concentrations of the acids since, although these were stated by the teacher, they were not written on the board or alongside the solutions. Inability to remember these details is consistent with the evidence that the capacity of the short-term memory is small (Johnstone, 1986). The combination of these details with experimental observations and existing knowledge that needed to be recalled was perhaps a cognitive 'overload'. Alternatively, it could be argued that in such an information-rich situation it may be difficult for students to distinguish between important and unimportant information unless the teacher pays explicit attention to these matters.

Class 11/2: Context

In the light of the findings with Class 11/1, some modifications were made to the manner of the presentation of the demonstration. The concept of pH was not introduced either before or during the demonstration, to ensure that this was not a confusing factor. The students remained in their seats and the demonstration was conducted in Petri dishes on an overhead projector. The formulas of the acids and their concentrations were written on the overhead projector to reduce the information load. The hydrogen ion concentrations of the hydrochloric acid solutions, and the indicator colours in each of them, were also written on the white board.

Post-demonstration discussions were more extensive and more searching than those of the previous presentation. In particular, rather than presume that students had experienced cognitive conflict, particular effort was made to ensure that the students recognized the 'discrepant event' before explanations were called for. The teacher engaged in considerable re-statement of what had been done.

Class 11/2: Findings

Seventeen students predicted that the colour of the indicator in the 1 M acetic acid solution would be the same as in the 1 M hydrochloric acid solution (yellow), and for all of these the observations presumably created a degree of cognitive conflict.

The students exhibited a better understanding of the demonstration than had occurred in Class 11/1. Their descriptions were more detailed and were generally a better reflection of what occurred. All of the students included reference to the acetic acid solution, and all but four stated its concentration. Ten students referred to the colour of the indicator in the acetic acid solution.

However, although the indicator colours had been recorded on the board alongside the hydrogen ion concentrations of the various HCl solutions, most students linked indicator colour to the hydrochloric acid concentration (rather than to the H^+ concentration). In this aspect, student understanding of the demonstration seemed no better than in the two previous versions. We did not check whether these students had understood that the hydrogen ion concentration and the hydrochloric acid concentration are the same but had seen no need to make this explicit in their responses.

Class 11/2: Discussion

Compared with Class 11/1, the ability to state the aim of the demonstration was improved. Even so, less than one-half of the students perceived an aim consistent with that intended. Many stated that the purpose of the demonstration was related to the properties of the indicator:

> To show how Indicator (sic) affect the different hydrogen ion 'concentrations'. To determine the acidity of acids of different concentrations by adding an indicator called methyl violet. The indicator can change colour depending on the extent that H^+ ions ionize.

Two fascinating examples of unintended, and undesirable, learning outcomes were exposed during the investigation. Both are easily understandable. Firstly, two students concluded that the indicator colour becomes darker as the hydrogen ion concentration decreases. This generalization is consistent with the observations, and presumably satisfied the plausibility criteria of the conceptual change model. Secondly, when they realized that the concentrations of the hydrogen ions in the two 1 M solutions were different, several students thought that they had resolved the conflict by deciding that the formula CH_3COOH showed each molecule could produce four hydrogen ions while each molecule of HCl could produce only one! This inference is clearly not an unreasonable one for novices to make. After all, how were they to know that some hydrogen ions are ionizable and some are not. Unfortunately, the 'Aha!' experience apparently had overshadowed the contradicting evidence that the acetic acid solution had the lower hydrogen ion concentration.

In both of these examples the students had arrived at seemingly viable explanations for the discrepant event. Unless further experiences demonstrate the lack of fruitfulness of their learning, it is possible these students will maintain these conceptions.

Class 11/3: Context

Of the three classes, the presentation to Class 11/3 seemed the most successful in regard to students' recognition of the purpose of the demonstration—as one might expect if the teacher had been learning from participation in this action research. In other respects, however, the demonstration seemed less effective.

Prior to the demonstration, the complete ionization of hydrochloric acid was discussed and the equation for ionization was written on the white board. The demonstration was conducted with solutions in Petri dishes on the overhead projector, and the hydrogen ion concentrations in the hydrochloric acid solutions were displayed on the board.

The post-demonstration discussion was more 'leading' than for other versions, but the search for a viable explanation was again left largely to the students. During this discussion, there was considerable evidence of students asking 'Why?', apparently in response to a recognized conflict. However, when the students did not converge on an explanation quickly and the teacher deferred 'giving the answer', many students showed frustration and adopted antagonistic behaviour, making caustic comments such as 'This is stupid!'

Class 11/3: Findings

Twelve of the 21 students predicted that the indicator would be yellow in the acetic acid solution, so one might presume that at least these students would have experienced cognitive conflict.

Consistent with the evidence that a good number of students identified the conflict appropriately, eight students expressed very clear and appropriate statements of the aim of the demonstration. On the other hand, consistent with the evidence of student frustration during the closing discussion, of the eight students who gave an appropriate statement of aim, only three wrote reasonably acceptable explanations for the observations. Two others showed that they were considerably confused:

> When an acid is diluted, it undergoes ionization. This lowers the pH value of the solution. As HCl is just hydrogen and chlorine, it is 50% hydrogen ions. CH_3COOH is less than 50% hydrogen ions as it has more 'impurities' (non-hydrogen) it will have a lower pH value.

Again, this student has demonstrated a plausible explanation. The student has correctly identified the conflict as the lower than expected hydrogen ion concentration, but demonstrates a poor understanding of the link between hydrogen ion concentration and pH.

As in previous classes, some students did not refer to the acetic acid in their description of the demonstration. Several students used the concept of pH, even though it had not been introduced at any point prior to the demonstration, and became confused. When asked for explanations of the phenomena, quite a few students simply re-stated the observations.

Class 11/3: Discussion

It seems that the teacher had indeed improved her ability to draw students' attention to the intended conflict. However, appropriate resolution of the conflict does not automatically follow. Although number of students resolved the conflict to their satisfaction, they did so by developing inappropriate learning outcomes.

The aggressive student behaviour is consistent with observations of Mitchell (1986) when students have expectations of the teacher as the provider of information rather than a facilitator of learning, and are not accustomed to a strategy in which they are required to propose and defend ideas.

General Discussion

Based on the evidence, one could hardly claim that this demonstration has been effective. It is apparent that with each successive modification there has been an improvement in the types and depths of understandings developed by the students. It is also clear, however, that some students may develop inappropriate and unintended understandings from the demonstration, and that many students cannot explain the observations well.

When examined in the light of the conditions required for conceptual change (Strike & Posner, 1985), it is perhaps not surprising that not all of the students achieved scientifically valid conceptual change. The first three aspects of conceptual change—dissatisfaction, intelligibility, and plausibility—can be achieved within the context of a single demonstration such as this one. The fourth aspect—fruitfulness—cannot necessarily be achieved with just one demonstration. We see evidence of this with the students who recognize the conflict and develop new conceptions. These conceptions, while plausible to the students for this demonstration, will not hold up upon exposure to further experiences. For example, the student who decided that the concentration of hydrogen ions was lower in the acetic acid due to the presence of more 'non-hydrogen' parts would see no reason to abandon this understanding unless presented with new experiences that counter this.

In spite of the many difficulties encountered with this cognitive conflict demonstration, it is not suggested that these types of demonstrations should not be used but that care needs to be taken with their presentation. It is also suggested that it may be necessary for further opportunities be given to students, particularly where it is apparent that inappropriate resolutions have occurred, to develop understandings that are both plausible and fruitful.

In the light of the findings of this demonstration, we suggest that the presentation to Year 11 classes require each of the following stages, explicitly developed:

- Establish (teacher authority) that hydrochloric acid ionizes completely in aqueous solution so that $[H^+]$ = labelled concentration $C_0(HCl)$.
- Label hydrochloric acid solutions with $[H^+]$ only.
- Demonstrate that the indicator colour depends on the H^+ concentration of the solution containing the indicator. Relate particular colours of methyl violet to particular values of H^+ concentration.
- Have students predict the indicator colour in the 1 M acetic acid solution.
- Note the indicator colour in 1 M acetic acid solution. Translate this to an estimate of H^+ concentration.
- Establish that the H^+ concentration in 1 M acetic acid is lower than in 1 M hydrochloric acid solution.
- Now focus on the puzzle of the smaller H^+ concentration in 1 M acetic acid solution than in the 1 M hydrochloric acid solution (rather than the difference between the indicator colours).
- Where evidence exists of inappropriate conceptual development, students should be given the opportunity to experience other, related phenomena.

Conclusions

Although, with hindsight, some of the deficiencies of demonstration presentation that have been identified in this study seem obvious, the researchers have been given cause to wonder how often they have confused students rather than enlighten them via the agency of classroom demonstrations.

This study of outcomes arising from the use of a counter-intuitive demonstration suggests that it is inappropriate to talk of the instructional effectiveness of a demonstration if the term *demonstration* is taken to be synonymous with a chemical event or phenomenon. It is apparent that the style and details of the presentation of the phenomenon (before, during, and after the phenomenon is shown), the suitability of the presentation for the purpose of the demonstration, and the closeness of match between what is demonstrated and the prior knowledge of the students are all factors as important as the phenomenon itself.

It is apparent from students' descriptions of the demonstrated phenomena that many of them had not recognized the 'punchline' of the presentation. Perhaps this is not surprising given the number of visual and verbal messages that they might have received during a short timespan. Johnstone (1997) has referred to the difficulty that students have in separating 'signal' from 'noise' during practical work, and the 'mental overload' that can result. Both Johnstone (1997) and White (1991) recognize the importance of selection for attention of particular events from all that happens around us. Indeed, Kang, Scharmann. Noh, and Koh (2005) report a correlation between field independence and the recognition of conflict in computer-initiated attempts to induce cognitive conflict with respect to the concept of density.

One mode of attack on this problem may be for teachers to try to reduce the 'noise' of demonstration presentations. Possible ways of assisting the students to attend to the key issue of a demonstration include the use of emphatic tones, dramatic (even melodramatic) style at crucial moments, reminding students of their predictions, pretended musing (aloud) to oneself, or even the use of a mock drum roll.

The findings here are consistent with the view expressed by Limon (2001) that conceptual change via the instructional strategy of cognitive conflict is not a function only of the students. Our evidence is that the success of these demonstrations is highly dependent on how the teacher interacts with both the phenomenon demonstrated, as well as with the students. This is consistent with the view of White (1994, p. 120) that 'the classroom debate has to be managed to that the scientists' view wins'. We support the view of Weaver (1998) that teachers may need professional development in order to effectively act as facilitators of learning in this mode.

This study provided evidence of some surprising cases of unintended learning. The different frames of reference of teacher and student may mean that an interpretation is made by the students that would seem quite unlikely to the teacher. This is perhaps a more likely happening in the case of discrepant event presentations than in the case of the more straightforward 'illustrative' demonstration presentation. The students reached what seemed to them a plausible resolution. A more scientifically acceptable resolution would require further experiences.

A contributing factor to the lack of motivation of some students to engage in the conflict resolution process may have been that they had not previously experienced a demonstration presented in a 'cognitive conflict' mode. Perhaps if the general expectation of students is to be 'taught' by demonstrations presented in 'illustration' mode, then it is expecting too much of students to adjust their expectations the first time they encounter this new style of presentation.

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