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Article Title: **Teaching For Understanding, Part II: Graphical Representations Of Dissonance And Conceptual Change**

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Abstract: This paper builds on concepts developed in the paper "Teaching for Understanding, Part I: Concepts of Conceptual Change and Dissonance" in this volume by Mary Anne Rea-Ramirez and John Clement. In Part I we discussed the fact that proponents of various strategies for promoting conceptual change have used a variety of terms and models to explain their particular method. These variations in language make the models more difficult to understand. Through the construction of diagrammatic representations of these models, in this section we attempt to explicate what some of the various major strategies of conceptual change are, in order to understand them more fully. In addition, we present some compound models which we feel express a summary of many of the available strategies from the research on conceptual change.

In Part I we argued for using a fairly broad concept of "dissonance" as a sensed disparity between an existing conception and some other entity. This can occur in mild as well as strong forms, as opposed to the term "conflict", which suggests only a strong disparity. We also presented a number of possible sources of dissonance, including: discrepant events, students' models and criticisms, and teachers' criticisms. In this paper we also discuss a different list of sources-- possible sources of ideas for model construction-- including: exploration and observations of materials, concrete examples, analogies, and suggested model elements. These have traditionally been seen as "positive" elements contributing to the construction of a new conception during learning, as opposed to "negative" dissonance producing elements during unlearning. We propose some representations for diagramming the effect of these sources of change on a student's conceptions, and illustrate this with diagrams of several approaches to teaching for conceptual change described in the literature.

We then go on to propose that the distinction between negative and positive influences is to some extent an illusion: sources of "negative" influence on an existing conception may also have "positive" influences on constructing a new model, and vice versa. In particular, we will contend that dissonance can occur as a result of the positive sources of model construction. This supports the conclusion from Part I that dissonance may be involved in CC in a multitude of ways.

The "positive" sources above then, instead of providing a single

effect on model construction of a new model, may also provide a second effect in that they argue against an older model. We generalize this concept of a "dual effect" to all conceptual change strategies by arguing that most of them could be sources of both construction and dissonance during learning.

These questions deserve empirical investigation through tutoring interviews and other means. We are particularly interested in the question as to whether different forms of dissonance can be helpful in conceptual change teaching, and under what conditions they can be a detriment.

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Teaching For Understanding, Part II: Graphical Representations Of Dissonance And Conceptual Change

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Completion Date: 8-21-97

ABSTRACT

This paper builds on concepts developed in the paper "Teaching for Understanding, Part I: Concepts of Conceptual Change and Dissonance" in this volume by Mary Anne Rea-Ramirez and John Clement. In Part I we discussed the fact that proponents of various strategies for promoting conceptual change have used a variety of terms and models to explain their particular method. These variations in language make the models more difficult to understand. Through the construction of diagrammatic representations of these models, in this section we attempt to explicate what some of the various major strategies of conceptual change are, in order to understand them more fully. In addition, we present some compound models which we feel express a summary of many of the available strategies from the research on conceptual change.

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These questions deserve empirical investigation through tutoring interviews and other means. We are particularly interested in the question as to whether different forms of dissonance can be helpful in conceptual change teaching, and under what conditions they can be a detriment.

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In this section we will develop graphic representations for several researcher's different views of conceptual change processes. We have already argued that dissonance can play a role in triggering or motivating a conceptual change. While the teacher or researcher may hope that the reaction to dissonance will be in the direction of change toward a more scientifically acceptable model, this may not always be the case. As suggested by Chinn and Brewer (1994), students sometimes have great resilience to dissonance and may choose to ignore or discard the source of the dissonance in favor of the already existing preconception. However, in this paper, we will focus on cases where it is assumed that there is some change in the structure of what the student knows based on the four outcomes proposed in Figure 1, Part I.

We begin by diagramming models of conceptual change that stress either dissonance or construction. Examples of these are found throughout the literature. Figures 1 through 6 graphically represent our interpretations of strategies proposed historically by researchers that were based on either dissonance or construction. Jagged lines are used in all of these models to indicate sources of dissonance for criticizing a conception. While the sources may often come from outside the student, e.g. other students, the teacher, etc., we mean to indicate that the dissonance that results is internal and occurs from an attempt to resolve differences in what is experienced or interpreted and a prior model. Straight arrows are used to indicate an influence contributing to the construction of a new model. M1 in these figures indicates the student's prior model, while M2 indicates a new conception being formed. Horizontal lines indicate a conception that is active over time.

In Scott (1991) early dissonance occurred between students as they attempted to understand their own theories. The source then of the dissonance was discussion and model criticism between students. Later the teacher introduced a scientific model and the student then struggled within him/herself to reconcile this model with the preconception (Figure 1). While this method promoted dissonance within the student, the research suggests that it also promoted construction of a more scientific model, M2.

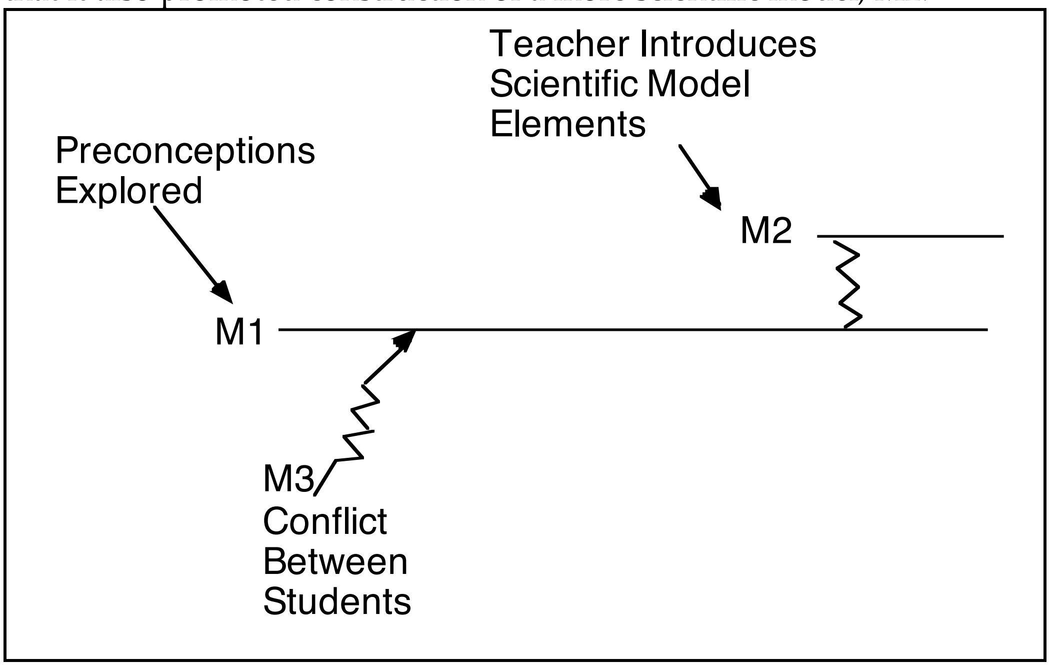

Figure II-1: Interpretation of Scott's (1991) Inducing Conflict model

Champagne, Gunstone, & Klopfer's (1985) model of Ideational Confrontation, a dialog based strategy, is represented in Figure 2. In this strategy the preconception of the student is brought to light through predictions about a particular situation. The student then develops a rationale to support these predictions. Students are encouraged to interact between themselves in a dialog in which dissonance occurs as students attempt to convince each other of their point of view or explanation for their own understanding of the situation. Late in the strategy the teacher may present a currently accepted scientific model and then encourage students to compare their predictions and rationale with those presented by the teacher. It is important to note that while dissonance occurs throughout the process, the teacher does not attempt to blatantly introduce dissonance in order to eradicate the preconception but allows the students to struggle with contradictory information and construct or reconstruct a new conceptual model for themselves based on new information and argument. In this diagram we do not commit to a particular transition model from Figure I-2 in Part I. M2 is represented not on the same horizontal line as M1 so as not to necessarily indicate a transformation from M1 to M2. That is, our diagrams are agnostic as to whether new conceptions are created by transformations or constructions or lead, in the end, to elimination of M1 or coexistence (distinctions we discussed in Part I). In fact, many authors do not use these distinctions in their descriptions.

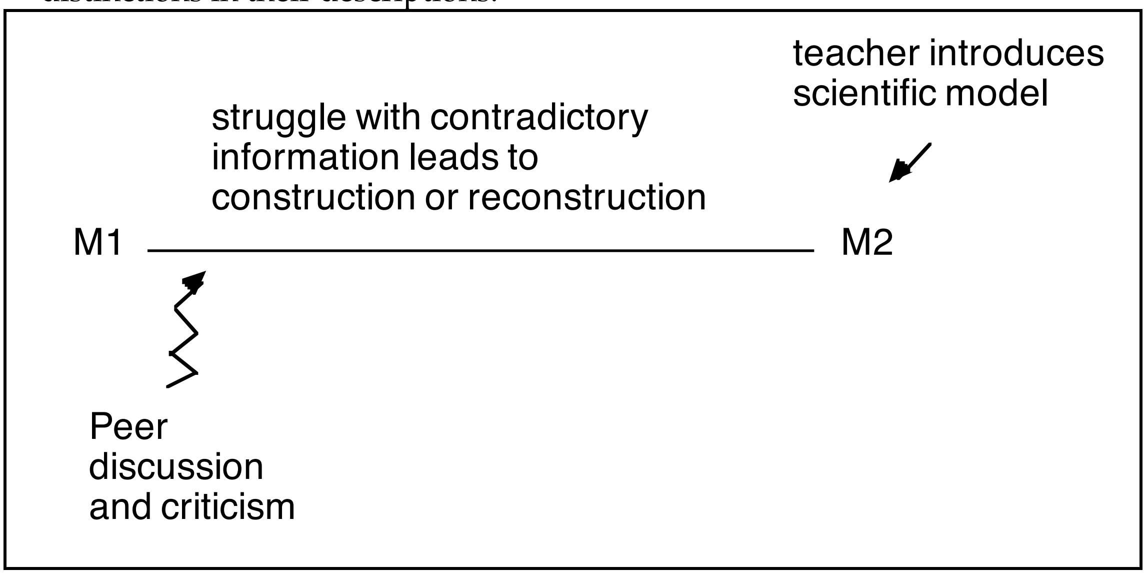

Figure II-2: Representation of Champagne, Gunstone, & Klopfer's (1985) Ideational Confrontation model

In the generative process strategy of Osborne & Wittrock (1983) students initially struggled with internal dissonance as they analyzed and attempted to explain their own preconception. There was then discussion between students with resultant dissonance and lastly, the teacher introduced the scientific concept which caused further dissonance as well as construction (figure 3). While construction of a new conception may occur, the emphasis is on dissonance. In addition, the final may be very different from student to student and may not be the same as the currently accepted scientific model.

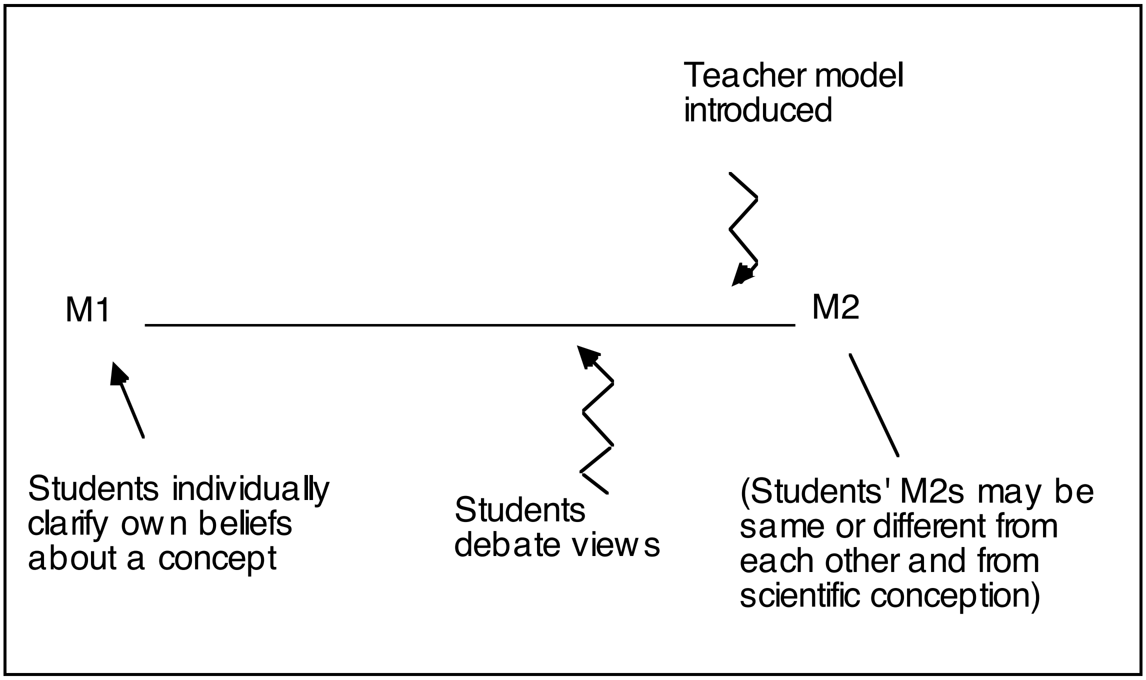

Figure II-3: Interpretation of Osborne & Whitrock's (1983) Generative Process

Jensen & Finley's (1995) strategy involved dissonance between students' preconceptions which were aligned with Lamarckian principles of evolution and Darwinian principles of evolution (figure 4). Two specific examples, one an experiment on rats done in the 1800's and a second example about the tradition of circumcision were taught to "place the students into cognitive disequilibrium". These examples opposed the Lamarckian principles studied earlier. Jensen & Finley's model of conceptual change differed somewhat from the first two in that the students' prior conceptions were specifically outlined by the teacher including examples of Lamarkian thought, and then a new scientific model based on Darwinian principles was taught. Further dissonance occurred as the students they tried to reconcile the two models when they attempted to apply them to problems.

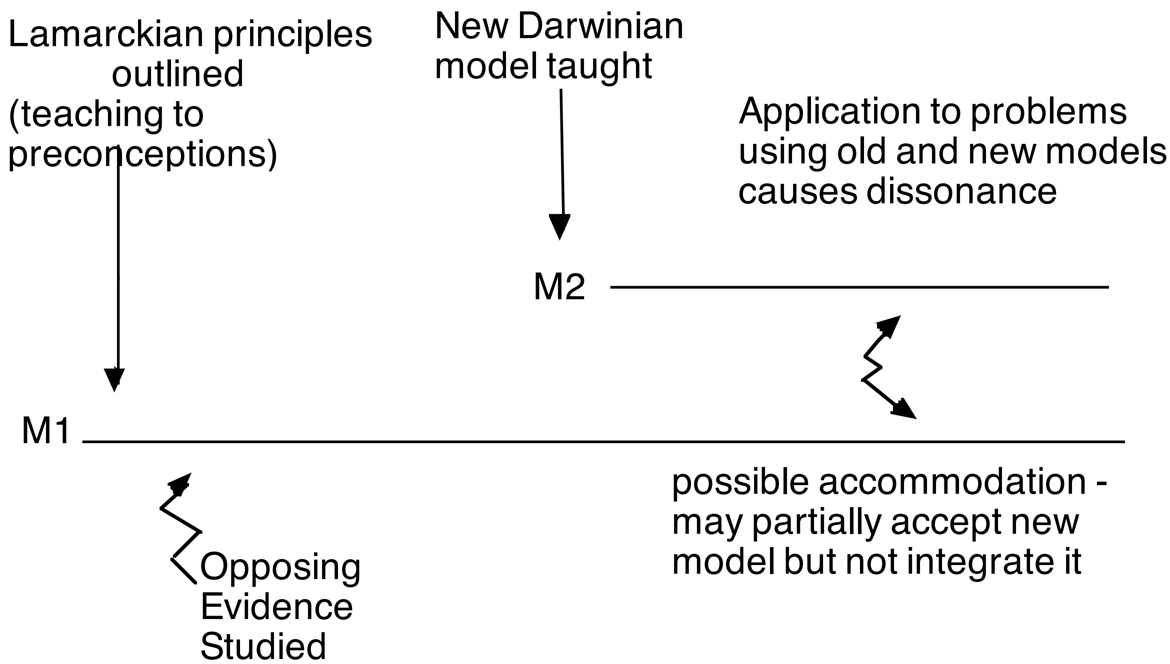

Figure II-4: Interpretation of Jensen & Finley's (1995) Teaching evolution model

Figure 5 illustrates Dreyfus, Jungwirth, and Eliovitch's (1990) "cognitive conflict" model of conceptual change. After identification of the student's misconceptions, dissonance was induced in the student through open-ended questions by the teacher. This dissonance involved challenging perceptions held by the student through Socratic dialog between the teacher and students. The student then struggled internally to resolve the dissonance created and to construct new conceptions on their own.

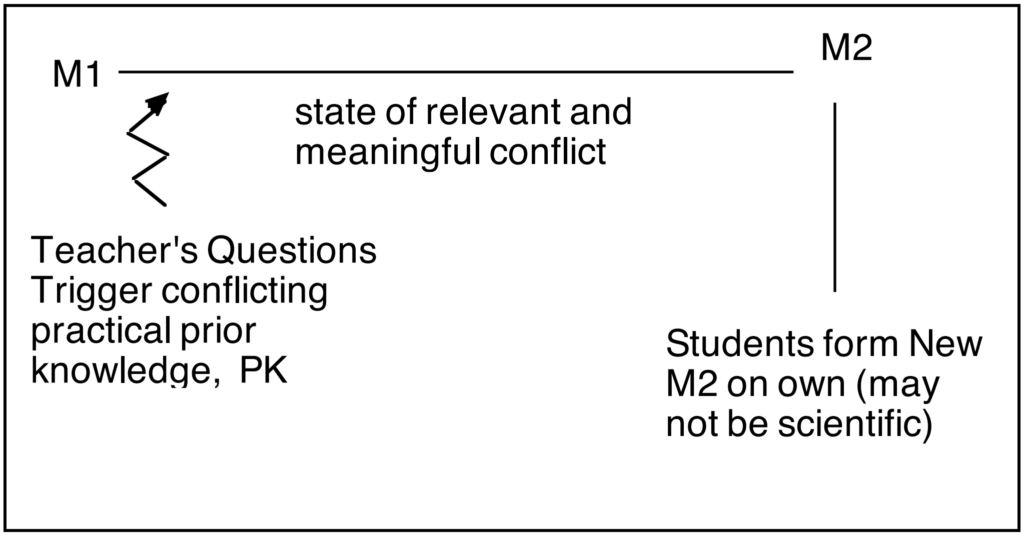

Figure II-5: Interpretation of cognitive conflict model of Dreyfus, Jungwirth, & Eliovitch (1990)

Presentation of external events to induce dissonance, however, does not necessarily lead to a commitment by the student to change nor to eliminate a conceptual model. The student may attempt to explain, reconcile, and possibly defend his/her conceptual model in relation to contrary evidence or discussion. These authors stressed, however, that, while the brighter, more successful students reacted enthusiastically to "cognitive conflicts", the unsuccessful students "have been shown to develop negative self-images, negative attitudes toward school and school tasks and high levels of anxiety. Anxious, feeling unsafe and threatened, they tried to avoid the conflicts." Research by Stavy (1991) suggested avoiding conflict to prevent students' loss of confidence and possible regression. (As was discussed in Part I this concept of conflict caused by harsh confrontation is not necessarily the same as the dissonance we suggest may play an important role in conceptual change).

It is for the above reason that other researchers have suggested avoiding confronting preconceptions but rather using preconceptions as a starting point or building block for construction of a new conception (M2). The use of analogies, observations, and peer interactions, encourages students to co-construct new models of understanding. Such a strategy is suggested by Glynn, et al (1995). This strategy employs analogies to help students build new models (Figure 6) and places emphasis on the construction of new conceptions rather than on dissonance production.

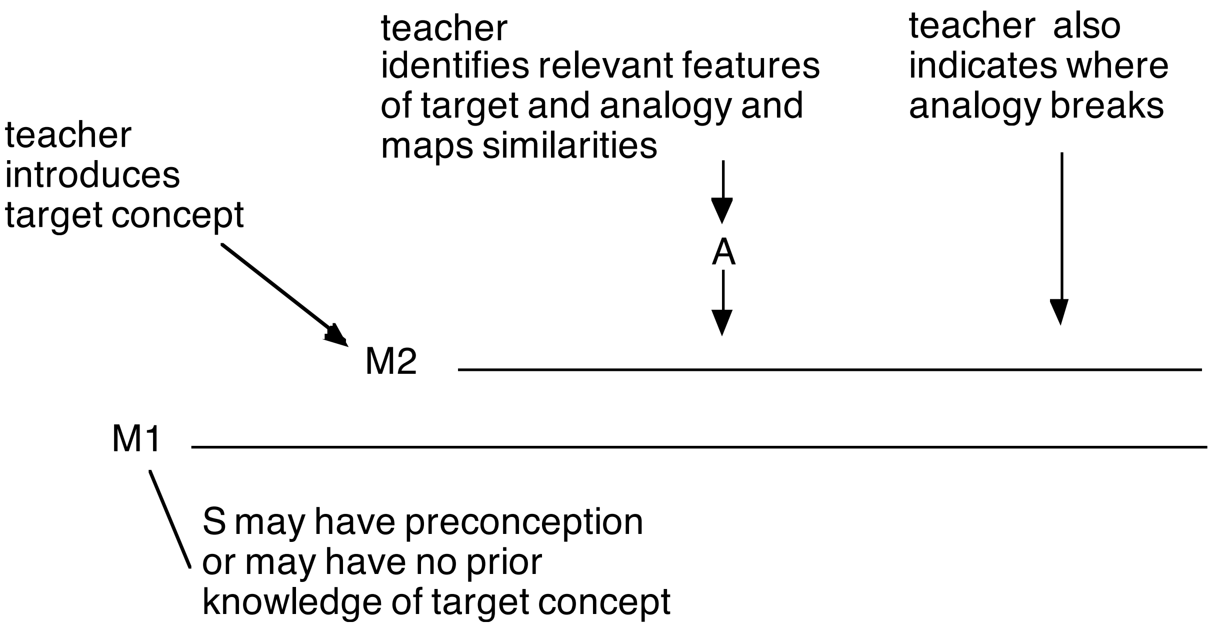

Figure II-6: Interpretation of Glynn'e (1991) Teaching With Analogies model

"Single Effect" Viewpoint

Much of the previous literature, can be summarized as advocating part or all of the modern "Single Effect" theory illustrated in Fig 7. This theory breaks model construction into stages namely:

1. Exploration of materials or in discussion to draw out preconceptions.

2. "Negative" sources: discrepant events or critical student and perhaps teacher opinions produce dissonance with the students' initial conception M1.

3. "Positive" sources: analogies, student ideas, or model elements suggested by the teacher are used to help build up a new conception M2.

An important point here is that the student's prior model is not the only preconception involved. Separate anchoring conceptions (labeled A) are other preconceptions that may be used to construct the new model. This model can be applied no matter whether the production of M2 is thought of as a new construction or as a transformation. Figure 7 serves as one possible summary of strategies described in the literature. However, unlike the graphic representation in figures 1-6, there is no indication of time in this model.

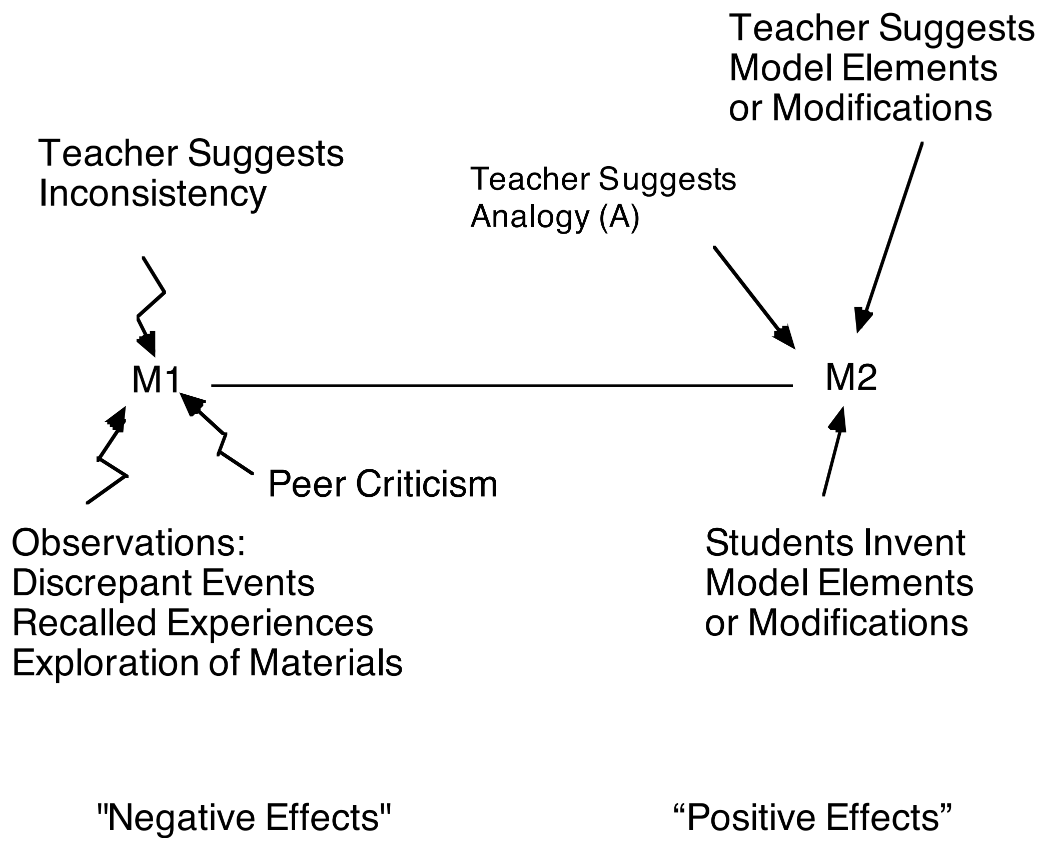

Figure II-7: Single Effect model

GOING BEYOND THE "SINGLE EFFECT" VIEWPOINT

We will now proceed to challenge whether the above distinction between "positive" and "negative" sources in conceptual change teaching is always applicable. We will exhibit a "positive" source that produces dissonance, and a "negative" source that contributes to model construction.

Analogy as source of dissonance:

One of us has reported that certain bridging analogies can motivate discussion via dissonance because they provide an example that can be assimilated to two competing and conflicting conceptions (Clement, 1993). The question of whether a book resting on a mattress is supported by a force exerted by the mattress can trigger both (a) the idea that springs can push back on an object pushing against them; (b) the idea that a passive object cannot exert forces on other objects. This example raises the possibility that analogies can not only be used for building new models, but can also be used to cause dissonance for old models. In general one might expect that an analogous case that supports a new model can promote some dissonance with an older competing model. So some analogies should have a dual effect.

Optimally Discrepant Events can help build a new model:

In a tutoring experiment in electric circuits described by Steinberg and Clement (1997), discrepant events were used to motivate changes in the student's initial model. However, they were also selected carefully to focus the direction of model revision or construction. That is, the discrepant event provides new data to be explained by a revised model; it provides a constraint under which the new model is constructed. The art of the teacher shows through in his or her selection of a discrepant event that is dissonant enough to motivate the student, yet raises a simple enough problem for the student to explain by revising their present model. We call this an "optimally discrepant event"- one that is motivating but that is not so discrepant as to be unexplainable or discouraging. Thus in this view discrepant events can have a dual effect in contributing to the revision or construction of the new model as well as to encouraging the student to move beyond the old model.

SINGLE EFFECT VS. DUAL EFFECT VIEWS

We generalize from these examples to formulate the following "Dual effect" hypothesis: Most influences on conceptual change can be sources of both construction and dissonance. This hypothesis shown as the "Dual effect" in view in Figure 8, conflicts with the "Single effect" view in Figure 7. There each type of intervention is shown as potentially providing both a source of dissonance with the prior model, M1, and a source of material or constraints for the construction of M2. For example, discrepant events, observations, and familiar facts can be used both as a source of dissonance (jagged lines) and as a support for construction (straight lines). Figure 8 can also be seen as a consolidated model of conceptual change based on dissonance and construction with support from the teacher and other students. By a consolidated model we mean a repertoire of possible processes that can be accessed for conceptual change teaching.

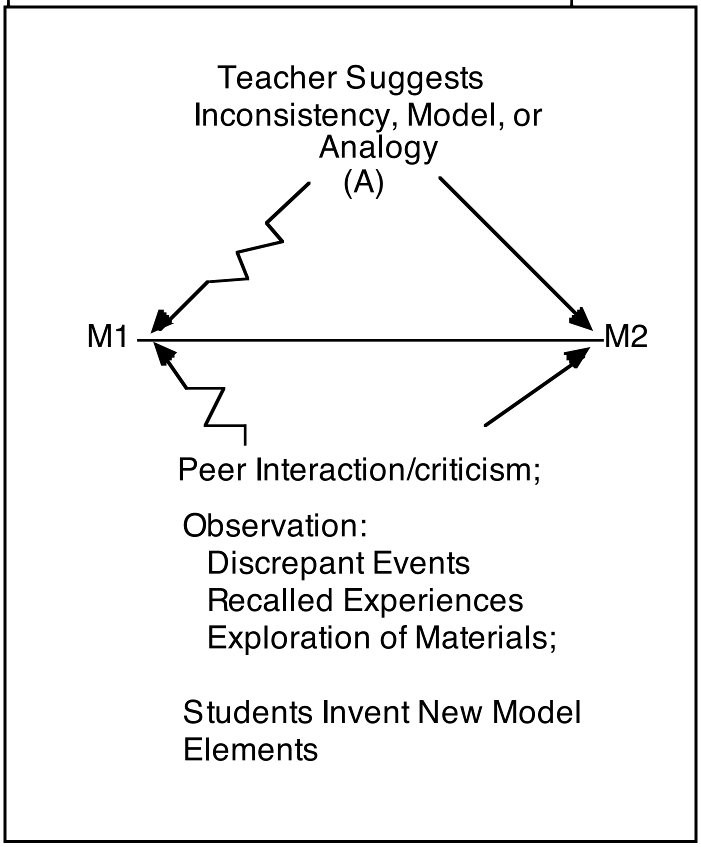

Figure II-8: Dual Effect model

EVOLUTION OF A SEQUENCE OF MODELS DURING MODELING CYCLES

For simple or shallow misconceptions, M2 may become the final model consistent with the currently accepted scientific model. However, for more complex conceptions, this may only be a beginning step in a cycle which will repeat itself many times until the final model is reached.

Figure 9 graphically illustrates an expanded version of Glynn, Doster, Nichols, and Hawkins' (1995) model of constructing new understanding of the structure and function of the human eye through conceptual change strategies. This model differs from those diagrammed in figures 1 - 5 in that multiple instances of intervention are used to gradually build a new conception (M2). Dissonance within the student is promoted through introduction of the concept to be taught by the teacher. Then a series of analogies and more new information are provided in order to gradually construct M2.

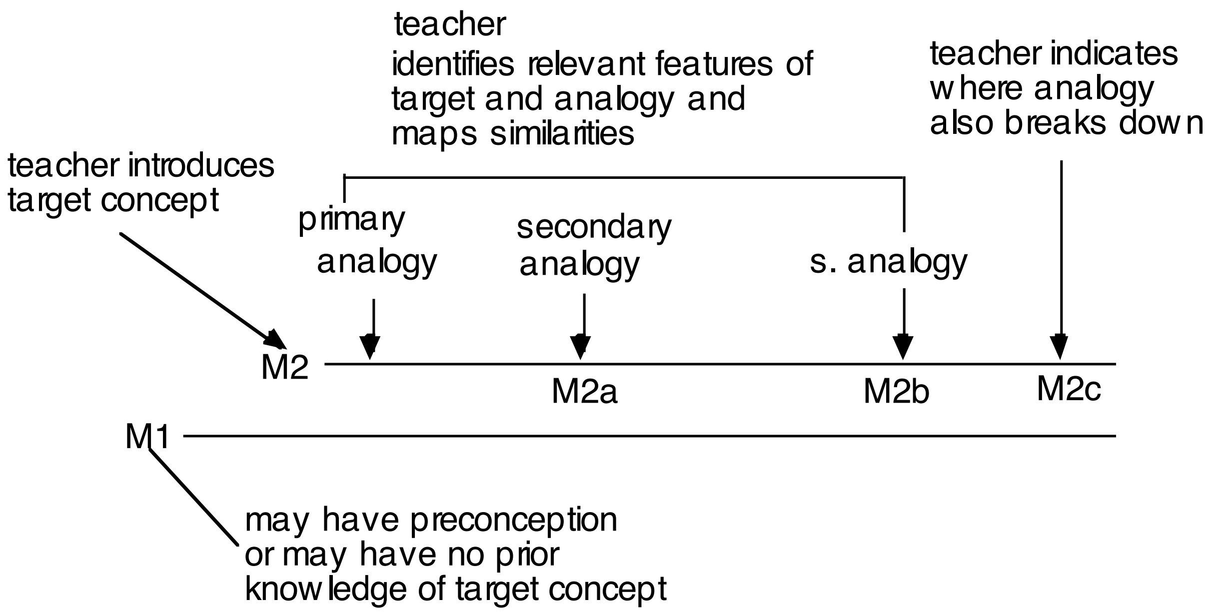

Figure II-9: Interpretation of Glynn's (1991) Teaching With Analogies model

Steinberg and Clement (1997) describe a teaching approach using simple circuits that attempts to move students through a series of progressively more complex models of electric potential and charge flow. The form of this strategy is shown in Fig. 10. At each stage a flaw in the existing model is found via a discrepant event or other source of dissonance, and then it is then repaired. The repairs often involve incorporating a new analogy. Such long term strategies may be needed for the development of more complex models. They term this approach "model evolution."

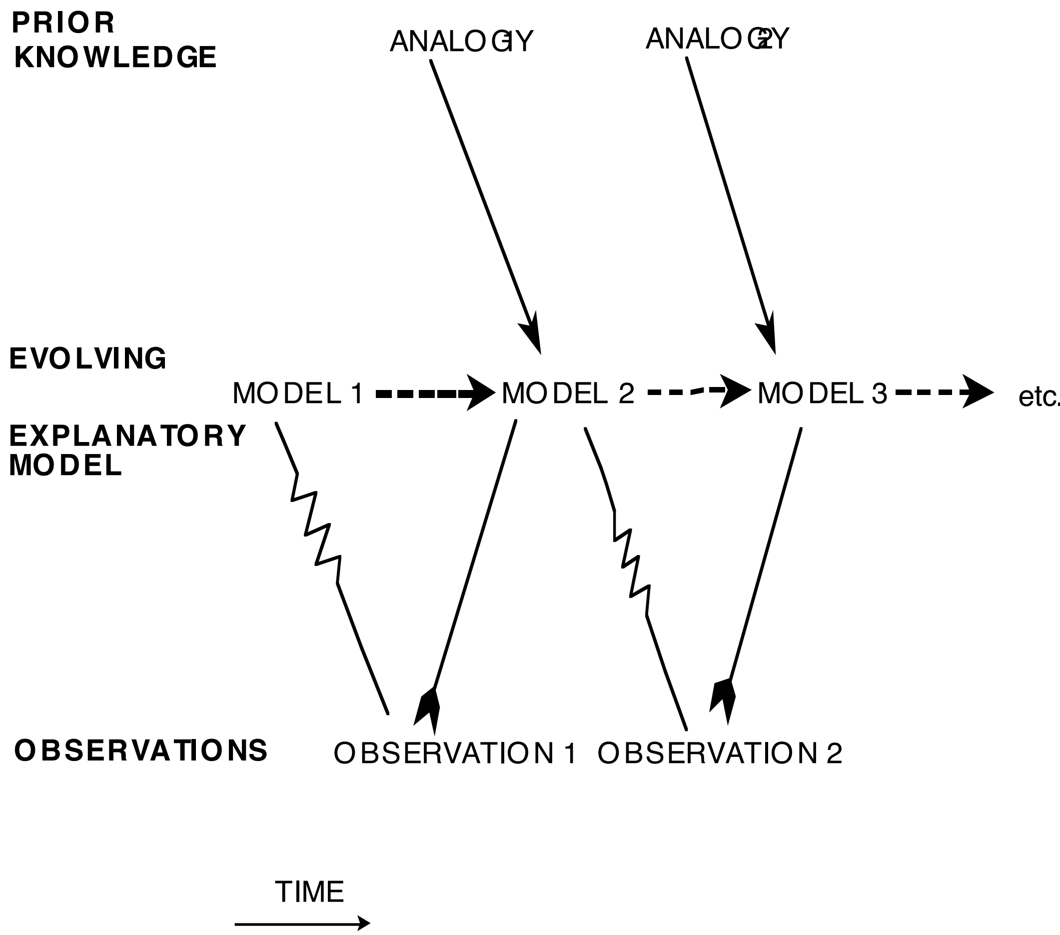

Figure II-10: Steinberg & Clement’s (1997) Model Evolution

CONCLUSION

In Part I we discussed a number of possible sources of dissonance during instruction, including discrepant events, other students' models and criticisms, and the teacher's models and criticisms. In this paper we have also discussed possible sources of ideas for model construction, including: exploration and observations of materials, concrete examples, analogies, and suggested model elements. While these sources have traditionally been seen as "positive" elements contributing to the construction of a new conception during learning we have hypothesized that they might additionally be producing dissonance. This supports the conclusion that dissonance can be involved in conceptual change in many ways. We proposed that a range of strategies which include discrepant events, exploration, analogies, and suggested model elements might play dual roles (both "positive" and "negative") in conceptual change methods.

The framework developed in this paper is a simplified one that starts from some simplifying assumptions, including a focus on cases where conceptual change can be described as a shift from an initial conception M1 to another conception M2 (with or without elimination of M1). We do not intend to imply that every influence must always have a dual effect on a prior model and a new model, or that every influence always causes dissonance, but that these are theoretical possibilities well worth examining.

We have additionally, proposed some schemes for diagramming the effect of these sources of change on a student's conceptions, and have illustrated this with diagrams of several approaches to teaching for conceptual change described in the literature. In addition, we have presented some compound models which we feel express a summary of many of the available strategies from the research on conceptual change. Our hope is that the diagrams may help us to compare and contrast proposed strategies, despite differences in the terminology used by different groups, in the search for better ways of teaching for conceptual understanding.

About the authors: John Clement has been engaged in research on learning in mathematics and science at the University of Massachusetts for the past 20 years. His current research is focused on methods for helping students form and use visualizable models in science. This research is enhanced by studies of mental models used by expert scientists during problem solving. He has published several books in this area as well as a large number of articles on reasoning and learning in science and math. His work has been funded continuously by the National Science foundation for the last 18 years. He has served on boards for the National Science foundation, National Science Teachers Association, and the National Science Board. In addition to his

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