ED 407 268 SE 060 207

AUTHOR	Beeth, Michael E.; Hennessey, M. Gertrude
TITLE	Teaching for Understanding in Science: What Counts as Conceptual Change?
PUB DATE	1 Apr 96
NOTE	24p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (St. Louis, MO, April 1, 1996).
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Concept Formation; Grade 6; Intermediate Grades; Learning Theories; Middle Schools; Physics; Problem Solving; Science Education; *Scientific Concepts; Teaching Methods
IDENTIFIERS	*Conceptual Change

ABSTRACT

In this study, a conceptual change model serves as a theoretical underpinning for analyzing what might count as evidence of conceptual change. Theoretical components of the conceptual change model include the status a conception has for learners, and the conceptual ecology of knowledge within which conceptions are believed to survive and have meaning. In an elementary school sixth grade classroom, conversations among students (n=29) and between teacher and students were recorded and analyzed to document claims about the role of status and the conceptual ecology to student learning. The following questions were addressed: (1) Does the teacher address theoretical constructs similar to those of the conceptual change model?; (2) What demands does the teacher place on the construction of knowledge?; (3) What conceptions of force and motion do students have following instruction?; and (4) What influences does adopting theoretical constructs presented by the teacher have on learning? Students regularly applied constructs of intelligibility, plausibility, and fruitfulness when discussing force and motion, and they recognized anomalies in their thinking and the implications these anomalies had for their thinking. The metacognitive abilities that allowed these students to comment on the status of their conceptions and to provide evidence for their ideas met the cognitive demands of learning in this classroom. (PVD)

TEACHING FOR UNDERSTANDING IN SCIENCE:
WHAT COUNTS AS CONCEPTUAL CHANGE?

Michael E. Beeth
The Ohio State University

and

M. Gertrude Hennessey
St. Ann's School, Stoughton, WI

Paper presented April 1, 1996 at the Annual Meeting of the National Association for Research in Science Teaching, St. Louis, MO.

SE060207

TEACHING FOR UNDERSTANDING IN SCIENCE: WHAT COUNTS AS CONCEPTUAL CHANGE?

Introduction:

Conceptual change currently occupies a seat of privilege in science education research. Nearly 3000 empirical investigations into various aspects of students' conceptions over the past twenty-five years testify to an intense interest in this field of research (Duit, 1993). It seems that everyone, teachers, researchers and those involved in educational reform, recognize a need to change students' conceptions from everyday views of science to the more powerful and rational ideas of contemporary scientific thought. Although the desire to facilitate change in students' thinking is a clear goal of research in conceptual change, what counts as conceptual change is a problem the science education community needs to address.

In this study, the Conceptual Change Model of Posner, Strike, Hewson and Gertzog (1982, hereafter referred to as CCM) serves as a theoretical underpinning for analyzing what might count as evidence for conceptual change. Theoretical components of the Conceptual Change Model include the status a conception has for the learner and the conceptual ecology of knowledge within which conceptions are believed to survive and have meaning (Hewson & Thorley, 1989). Conversations between students and between teacher and students were recorded and analyzed to document claims about the role of status and the conceptual ecology to student learning. The following questions about conceptual change teaching and learning were addressed during this study:

- does the teacher address theoretical constructs similar to those of the Conceptual Change Model, and if so, how?;
- what demands does the teacher place on the construction of knowledge in this classroom;
- what conceptions of force and motion do these students have following instruction?; and
- what influences does adopting theoretical constructs presented by the teacher have, if any, for learning?

Cognitive demands of teaching and learning science:

Teaching and learning science have become increasingly complicated tasks. It seems that everyone connected with science education wants students to understand science content at some deeper, unspecified, level. Coupled with this desire is a goal to have students understand the nature of science as an intellectual and cultural activity. Reform initiatives (e.g., Project 2061 and The National Science Education Standards in the United States) in science education call for more attention to the nature of science while maintaining ample coverage of science content. Added to these pedagogical changes in what gets taught is a call from researchers in science education that teachers pay greater attention to how students learn.

When taken as a conceptual whole, pedagogical practices that address science content, the nature of science, and how students learn science presents a daunting task to any teacher. How could any well meaning teacher address all of these adequately, given the pressures and contexts of contemporary schooling? A single answer to this question is not possible. The best that can be expected is multiple interpretations that help students change in one or more of the areas described above. What would be helpful in beginning to understand dynamic interactions between science content, the nature of science, and psychological aspects of learning is a theoretical model with practical applications to classroom instruction. Posner, Strike, Hewson and Gertzog's (1982) Conceptual Change Model contains theoretical components that inform teachers and researchers about what might change for students and the influence these changes could have in terms of learning.

Theoretical components of the Conceptual Change Model:

The Conceptual Change Model of Posner et al. (1982) assumes that students' ideas play a critical role in learning. Students' ideas, in their current form, must be taken seriously by teachers and researchers and treated equally with the ideas of the scientific community. Changes in the status of students' ideas (i.e., from unintelligible to intelligible,

intelligible to plausible, plausible to fruitful) are indicative of change in a conception (Hewson & Thorley, 1989). The processes through which conceptions have changed in the scientific community, such as historical views depicting the structure of the atom, are thought to be analogous to changes in the thinking of students. Detailed descriptions of the role and function of theoretical constructs proposed in the CCM can be found in Hewson and Thorley (1989), Hennessey (1991), Strike and Posner (1992), and Thorley (1990) and not presented here.

Conceptual change for learners:

There are significant differences in how students come to change their conceptions however. First, students do not belong to nor have they necessarily adopted the standards by which the scientific community judges knowledge claims. Kuhn (1970), Lakatos (1970), and Markhews (1994) point out some of the standards used in the scientific community to justify and explain what counts as knowledge. Changes in these standards are infrequent although they do occur on a historical time scale and have profound impact on what is recognized as knowledge. Changes in students' conceptions are loosely based on an analogy to changes within the scientific community (Posner, et al. 1982). The theoretical constructs of the CCM include a conceptual ecology, within which conceptions survive and have meaning, and the status of a conception (Hewson & Thorley, 1989). The status of a conception is related to the intelligibility, plausibility, and fruitfulness of a conception to the learner. Components of the conceptual ecology include anomalies, analogies and metaphors, epistemological commitments, and metaphysical beliefs. Students' abilities to comment on the status of a conception and components of their conceptual ecologies may not contain components similar to those of the scientific community at the beginning of instruction. However, it is reasonable to expect changes in these components during or following instruction that addresses these components.

A second difference is that psychologically speaking, components of the CCM (i.e., status and the conceptual ecology) require thinking about abstractions rather than objects in the material world. Successful scientific ideas frequently make claims about objects in the material world and the phenomena they experience into abstract principles. Physicists think of pendulums as point masses at the end of weightless strings rather than heavy ball suspended from a support (Markhews, 1994). Learners are seldom required to express their thinking at this level of abstraction or asked to generalize their thoughts to classes of phenomena in much of contemporary teaching. When learners do make reference to abstractions about material objects they move their thoughts to a level of abstraction more in line with those of the scientific community. It isn't the material objects themselves that become abstractions but the psychological construct's students are thinking with--their conceptions. Comments about the limitations of a conception should also be considered a sign that either conceptual change has happened or is potentially possible. The latter point is supported by the notion that learners need to recognize and respond to anomalies in their own thinking (re.: the anomalies' component of the conceptual ecology). Recognition of anomalies in how you think about abstractions from the material world place learners at the point of dissatisfaction referred to by Posner et al. (1982).

Theoretical constructs of greatest importance to the Conceptual Change Model are metacognitive in nature and seldom expressed directly by students. One notable effort to make metacognitive thought explicit, The Project to Enhance Effective Learning (PEEL: Monash University, Australia), attempted to teach secondary students metacognition as a component of how they learned science (White & Gunstone, 1989). Explicit attempts were made to present students with metacognitive strategies as they learned. Students in PEEL expressed considerable resistance to engage in the efforts necessary for metacognitive reflection (White & Gunstone, 1989).

A third difference between the way knowledge changes in scientific communities and change in students' conceptions has to do with application of a change. Changes in ideas may not be as immediately fruitful for students as they are for scientists. Learners seem to attach individual ideas to specific situation while (some) scientists recognize the fruitfulness a change in conception has for thinking about whole classes of phenomena. This is an absolutely crucial point in conceptual change teaching and learning. Again, it must be noted that recognition of this point in learning and reacting to it does not guarantee a change in conception. Students frequently fail to see the fruitfulness of a conception, perhaps because they lack sufficient experiences with a particular phenomenon.

A fourth difference between the scientific community and students learning science is that students' and scientists do not typically share the same epistemological commitments and metaphysical beliefs. Commitments to rational explanation, consistency in explaining phenomena with the same causes, and generalizabilitiy of a specific instance to larger classes of events are some of the epistemological commitments of the scientific community (Hewson, 1985). Students tend to reason from anthropocentric points of view (i.e., 'I exert a force...') and frequently fail to see the inconsistencies in their thought patterns. Changes in students' thinking from a personal point of view, the internal consistency of an idea, and the generalizabilty an idea has for explaining phenomena are what need to change in addition to change in science content knowledge.

Design of the Study:

The content of this study included teaching pre-college physical science (force and motion) in science classes designed especially for elementary students. The teacher/researcher selected for this study is an Elementary School science teacher with twenty years of teaching experience. The setting, an Elementary School sixth grade classroom with a total of twenty-nine students (age's 11-12), was observed during two separate academic years for a total of 11 months. The teacher in this setting was 'experienced' in that she routinely elicited the status of students' thoughts during instruction. The teacher selected for this study currently participates in action research projects of her own design. Her scholarly works include collaboration with science educators at a number of university in the United States.

Questions for this study included does the teacher address theoretical constructs similar to those of the Conceptual Change Model, and if so, how?; what demands does the teacher place on the construction of knowledge in this classroom; what conceptions of force and motion do these students have following instruction?; and what influences does adopting theoretical constructs presented by the teacher have, if any, for learning?

Instruction in the classroom was documented on video tape and in daily field notes. Transcripts of classroom discourse were analyzed to document the cognitive demands this teacher presented to students during her instruction and what changed for students as they learned about force and motion. Data sources were initially examined to determine which theoretical components of the Conceptual Change Model were included in the teacher's instruction. Analyses of students discourse followed to verify if students adopted these constructs and what impact adopting these ideas had on learning. Analysis of data is reported at the level of the class as a whole to provide an overview of change is students' thinking within this classroom environment and should not be assumed to indicate change for all individuals participating in the study.

Teaching and learning of force and motion:

The teacher in this Elementary School classroom allowed students multiple opportunities to construct their own understanding of force and motion. For this teacher, the interplay between the science content (i.e., force and motion) and how students came to the point where they could facilitate discussion of their own ideas was critical. The students' abilities to discuss ideas on their own were facilitated by helping them deal with the status of an idea and to continually develop their ability to provide reasons underpinning an idea. In the analysis that follows, the teacher's voice is presented first to establish the level of cognitive demand she sought to promote through her instruction. Excerpts from student discourse are presented next to indicate the degree to which they were capable of responding to the teacher's instruction.

Developing and applying an understanding for the construct of status (e.g., intelligibility, plausibility, and fruitfulness) were activities this teacher visited many times throughout her instruction. She initially approached the construct of intelligibility directly, as in the excerpt following taken from a series of lessons on building a mutual definition for the construct of intelligibility.

> t: so it seems like most of the things that you were trying to answer on that little quiz is to be intelligible something has . you have to understand the words . and then the words have to convey an idea . and that seemed to be coming out on almost all of them . do you feel comfortable with that

Key to transcription marks:
t: = teacher
s: or s's: = unidentified student(s)
r: = researcher
v: = visitor to classroom
. . . = one second pause/period
[] = comments inserted by transcriptionist

Students constructed definition for plausibility and fruitfulness as well. The following excerpt contains a reference by the teacher to the utility of the constructs of intelligibility, plausibility, and fruitfulness.

> t: OK . . so I think . you know . we're trying to use some words that will help you explain your ideas a little bit better . because if you have ever tried to talk about something . and you find out 'I can't say it . it doesn't come out the way I want it to...' . . . so I think we're using intelligible . plausible . fruitful. just as a little bit more powerful way of trying to talk about your ideas . and it takes a little bit of time to develop that power . OK

After working with the status language, the teacher took every opportunity to have the students operationalize this construct during instruction. On multiple occasions she reminded students to apply these constructs as they listened to and discussed ideas related to force and motion.

> t: . . first of all listen to the group that's talking . see if you understand what it is they're talking about . . if you don't understand what kind of questions do you need to ask in order to understand . forget about do you agree with it . you need to understand it first . all right . once you can understand what it is they're talking about and you happen to disagree that's all right but you need to understand what's going on here first okay/ . so you don't want to sort of jump in and say "I disagree" you don't even know for sure what it is they're talking about. so perhaps if you don't see it the same way you might want to ask some questions as to why they think that's the way of describing the forces . now remember everybody getting up here is possibly trying to describe what they think is the best way . the best explanation for that activity . you may disagree with it . so in some sense you probably want to find out why do they think that's a good explanation

Defining the status terms of the CCM is a regular part of this teacher's instruction (Beeth, 1993; Hennessey, 1991) and students routinely to apply their conceptions of status during discussion of science content. Several examples of status related statements from different students and different contexts are presented below.

Example 1 (differentiating intelligibility from plausibility)

> Pete: well I understand the words . but . I don't like . um . I don't . if you can like picture an idea of that . I . I don't picture an idea of it <r: ah hum> so it would be unintelligible to me
>
> r: it would be unintelligible to you. . OK . is it that . um . let's see if we can make a distinction here
>
> t: yeah
>
> r: is it because you don't understand the words and the idea or is it because you don't believe the idea is true
>
> Pete: I don't believe the idea is true

Example 2 (status discussion applied to science content)

> Kirsty: OK at rest and moving at a constant speed in a straight line <t: mm-mm> I don't get like what well they mean . I get like what the sentences mean but I don't know if she means like at rest would be just like set it there or if you like throw it and it would just be at rest . I don't get it
>
> t: yes . obviously then you have to say what does this stuff mean . . because like any definition . a definition's just words . and I could write a definition for what motion is . but it would just be words

Example 3 (discussion of a mass suspended by a spring)

> r: why do you like that idea better than the others

Kirsty: well because . well I really didn't think of it as rest I was just thinking of it as suspended . I really didn't think about that so I was just looking . . . I wasn't really looking at it if it was at rest or not

r: what were you looking at though

Kirsty: I was just looking at like . . well. . pretty much I was just looking at the weight I wasn't thinking of it as like suspended

r: OK

Pete: you weren't thinking of at rest right

Kirsty: uh uh [indicating no]

Instruction in the force and motion unit included a series of demonstrations (see the Circus of Physics Demonstrations in Beeth, 1993) during which students were to carefully observe very specific motions. For example, when tossing a ball upward the teacher emphasized what motion to be observed in the following: t: observe the motion of this ball <u>ON THE WAY UP</u>. The decision to focus the students' attention through specific directions carried through to these students as will be apparent later when they discuss how objects are moving. This is an important pedagogical step in the instruction of physics (and all science for that Marker) because there are many observations that students can and do make that are not related to the phenomena of interest.

Although the teacher gave explicit instructions on which motion the students were to focus upon, she gave no indication of how students should describe that motion on slips of paper she provided. Once the observations were complete she asked students to place the slips of paper into groups with similar motions. Her interest in having student's state and work with their own thoughts is a hallmark of her instruction. This approach is consistent with strategies conducive to conceptual change teaching (Hewson & Hewson, 1988). The following excerpt contains several aspects of the intellectual environment this teacher sought to provide for students in her classroom.

t: . . . you had an opportunity to look at some items that were moving . . . and what I asked you to do as you watched these different items . was to find something that was

> important or significant to you . and to write it down on a piece of paper . . the next thing I asked you to do . is to sort of sort those out in ways that were meaningful to you and the last thing we did is . . . put on the board all the ideas and things that you had down . . and the list looks about this long . . by the time you type it all out . . . see it [shows list to students] . lots of things down there . . lots of ideas . lots of things that you saw important to look at . . but as I look through them . some of the things that I noticed that often what you looked at were something called cause agents sometimes you chose to focus on [the causes of motion] . I think it was a cause agent . or another way of looking at that is [writing on white board] OK . so you are looking at what caused the motion for example . pushes . pulls . kicks . tosses . or whatever else you could have written down on there . . so sometimes as you were watching the item you chose to focus in on the cause agent . . . . . . the second thing I noticed is that many times you chose to look at the effects . another way of saying that is [writing on board] what happened during the motion . OK so that's some of the other things you chose to look at . . . the items speeding up . . the items slowing down . its going faster . its turning around . so many of the things you looked at were cause agents . um many of the things you chose to look at were the effects . but what I'd like you to think about for now at least as we are going through this unit is . toward the end of the unit or as we progress through the unit . um the [goal] is to try to build some understanding if you like of the relationship between cause agents and the effects . . so if you can walk out of this unit with . 'Oh I think I have some understanding between the cause agents and the effects' then perhaps if you are walking away with some useful or some powerful information that you can use as you move through the science classes and move on to more physics in middle school and high school . all right . so its not necessarily that you are walking away with a perfect explanation of force and motion . that won't happen in one year . we just don't have enough time in one quarter . but if you can walk away with an understanding that there is a relationship between these two things and I think I have an understanding of that relationship that's something you can use you can use in some of your other classes and things like that

The excerpt above illustrates two points about this teacher's approach to instruction. First, she begins instruction with what makes sense to the students by having them observe and classify the motion of objects in their minds. The categories that make sense to the students include speeding up and slowing down and are obviously not in agreement with the current Physicists' views on acceleration. The teacher indicated in private conversation that she knew this idea was not in agreement with canonical views of science but felt it was essential that students work with the ideas they had constructed until they could "go no further with their ideas." Later she did propose categories of motion that are in agreement with those of Physicists but at this point she felt it was essential to know how these students were thinking about the topic.

It is also clear from this excerpt that the learning goal this teacher has in mind is for students to understand that there is a relationship between the causes of motion and the effects of motion. She makes this point from her analysis of the categories presented by the students. It is not readily apparent to these students that there is a difference or that the difference might be important to their understanding of the concept. The distinction drawn by this teacher parallels the distinction in Physics between dynamics and kinematics and is fundamental to understanding not only how objects move but why they move. The actions of the teacher help move the learner from their perceptions of motion to more abstract thinking about what would cause an object to move. In short, the teacher is establishing that, in this classroom, you must be able to move beyond the world of physical descriptions to the psychological world containing abstractions of those experiences.

This point is further substantiated by the teacher when she refers to the difficulty of learning a concept of force and motion. She acknowledges the real difficulty student's have in learning this concept and implies that what they are able to understand in the time allotted to this concept will change in the future. The notion that what students are to learn is temporal and subject to change is not a common experience in much of a student's experience. Memorizing facts and information for the purpose of passing an examination are much more commonly accepted as the pragmatic means for learning.

Another point that surfaces repeatedly in the instruction of this teacher has to do with supporting knowledge claims. Although she accepted all ideas presented by her students without sanctions, she did have one clear requirement of these students--that any idea presented contain the reasons why you think your idea is valid. Statements like the following were commonplace in this teacher's response to ideas presented by students.

> t: OK . anybody agree with that or disagree with that . or have some reasons for agreeing or disagreeing . . if you agree can you have some reasons . . what are your reasons for agreeing

and:

> t: one person is saying . perhaps . the trolley on the string is changing speed . one of the things you might need to consider . . is it [changing speed?] . is it really . <s's: yeah> OK what evidence can you gather . . what evidence can you gather from the fact that it is changing speed if indeed you think that it is

This teacher's request that students continually develop the ability to provide justification for their conceptions is consistent with that portion of the Conceptual Change Model contained in the conceptual ecology. During instruction she suggested a number of ways in which students might think about representing their ideas. The two extracts below refer to consistency in reasoning, one component of the conceptual ecology.

> t: OK . and if sometimes if you find yourself looking at the same situation or in the same situation . then maybe you need to start looking . the same situations may need the same explanations . different situations need different explanations . and sometimes you can't always recognize that you're working with the same situation . but you want to try to do those kinds of things . OK . ask yourself is this the same as . um . is this the same as this . is this the same this . and if you end up saying no it's not . but if you end up saying yes . then it'd be pretty strange if I walked over here and said well I'm going to let this go . and you say it's going to stay right there . if I walked to the other side and was going to let this go and you said it fell . you know . you've got a different description for the same situation . that doesn't make a lot of sense . humm/ now . but sometimes you just can't recognize that you're working with the same situation . so try to ask yourself that as you move along . OK

and:

> t: OK the situation hasn't changed . so if the situation hasn't changed . the explanation hasn't changed . all right . now can you take a look up here for a minute . one of the things we just sort of saying . if you've got the same situation . you might want to look for the same explanation . OK . . if you have a different situation you may have to look for different explanations . OK . . so let's just concentrate on the same situations . same explanations . all right

Students responded to the teacher by seeking physical evidence that would help them decide of an object changed speed or not. The following extended transactions between teacher and students illustrate the students' abilities to engage in this cognitive act.

[Looking for evidence, deciding which motion to focus on]

> t: . . . what were you working specifically on last week . . . last Thursday . . . yeah Thursday, Friday, Saturday, Sunday . . four days ago
>
> Dan: well we were working on how.. fast it goes . and how you get how fast it goes

t: OK . and I heard somebody else . saying . I was working on how to figure out speed here and you are saying how fast it goes . . OK

Dan: like how many centimeters it goes in like a certain amount of time

t: OK distance over time . or distance in relationship to time . OK . and I think one of the things I'd like you to sort of think about is . are the items changing . you are looking for some change . so if you went through this whole list . . . . think about the motion of that ping pong ball . . do you think the motion is changing or not changing

Jim: changing

t: OK . why

Jim: um . no matter how hard you hit it . it changed directions . its not gonna hit the same spot on the paddle.

t: OK think about motion . . first of all . . and you are trying to describe that motion whether the motion is changing or not changing . forget the causes . . OK we are not working on causes right this minute . . OK . . . the paddle being a cause

Jim: which motion . the motion that goes up and then back down . or the motion of the ball [spinning in a circle]

t: OK the ping pong ball . . the motion of the ball . . here is this ball . . its traveling in an upward direction right

Jim: yeah . its spinning around

t: OK so what do you want to look at . . do you want to look at direction . . you can you can decide not to look at direction . . and I want to look at motion . . what you are trying to do . is determine whether its a changing motion . or a non changing motion or a steady motion

This exchange between teacher and students is typical of many that occurred in this classroom. The teacher helps these students focus their attention on the vertical motion of the ball rather than the rotational motion and the students comply. This was a necessary decision since what the students really needed to think about next was the evidence they could find for the motion of the ball. It is unlikely that these students would have been able to determine anything about the rotational motion of the ball but they could be expected to calculate both speed and time in order to determine speed. The speed of this ball at various points along its path would provide evidence to address the teacher's question about whether the ball's motion is changing. In this instance the students focus their attention to the vertical motion of the ball and they indicate that measuring the distance the ball travels in a given time would provide the evidence for determining if the ball is changing speed.

The following excerpts occurred primarily between students. On rare occasions, the teacher, the research and a visitor to the classroom (a science education researcher) asked questions of the students. In the following exchanges between students it should be noted that they are applying many of the cognitive constructs that the teacher initially taught (e.g., status and providing reasons for ideas).

[discussion of forces acting on a book at rest on a table]

Nancy: book on table . . it just stays there . . it's not like it's going to go

Greg: what is it [you said]

Nancy: it's not going to move all over unless you have opposing forces on it

Mary: but what's the other force

Nancy: gravity

Greg: gravity and what

Nancy: I don't know

Mark: the gravity is pulling it down and causing it to stay

Mary: what's the other force though

Greg: yeah what's the opposing force . gravity and what

Nancy: the table

Mary: but that's not

nancy: if you just put it right here

Mark: the table's the agent

Mary: gravity is pulling the book to the table

Nancy: but if you put it out here . . there's no table and it's just going to fall straight to the floor . . gravity is pulling it

Mary: but this table has gravity and it's pulling it

Greg: the table doesn't have an effect on it . this gravity has effect on it here . and here . the table only has effect on it here and not here . . so the table is not a force

Mark: it's an agent

Nancy: yeah so what's your other force

Mary: there isn't two forces . OK

s: oh my gosh

Nancy: so which one do you think it is

Mary: you only have one force though

Greg: it's equal

Mary: what's equal . there's only one thing so how can it be equal with something else

Mark: well it's just gravity . it's just gravity . one arrow [representing the force of gravity] . so it'd be at rest . balance . it at rest

Greg: it is [at rest] . I know . that's what I say . balanced [forces] . at rest

The science content in this exchange is clearly about the number and nature of forces acting on the book at rest on the table. These students, working in a small group, expressed their ideas about this content and examined their rationale for believing in one force as opposed to two. They are not sure where a second force could come from, if it is present. They indicate that if there is a second force it would have to come from the table. They discuss the idea that an object at rest needs to have balanced forces for an explanation, however, they are uncertain at this time if the table could cause the second force or if they are merely an agent interfering with the pull of gravity. While these students do not give solid evidence of adopting canonical views associated with Newton's Second Law, they have reasoned through their ideas and have come to the point where they know that they need a reason for how a table might produce a force, if it does.

Conceptual changes for these students include recognition of an anomaly in their own thinking. If they want to think of the book as being at rest, and if objects at rest have balanced forces, then they need to know where the second force could come from. This raises a metaphysical question about the nature of tables and inanimate objects in general. If students believe that forces must come from the actions of living organisms, they will not be able to understand the physicist's notion of passive force. Although not indicated in the excerpts above, these students dealt next with the metaphysical characteristics of tables--how could a table produce a force?

The next exchange involves discussion of a mass suspended from a spring. The canonical explanation involving Newton's Second Law should apply to this case as it did to the book on the table.

Mary: who did suspended weight

Mark: me

Mary: what did you put

Greg: OK . . that the forces are equal so the weight doesn't move

Mary: but what are the forces

Greg: gravity . . . it's pointed so it doesn't move.

Mary: but what's the opposing force . . the spring

Greg: yeah . . well the spring and the force

Mary: well that's the agent

Greg: it's holding it up there though

Mark: which one would you pick..

Greg: a . . . cause they are equal . . this is equal . . this is when gravity is winning and this is the spring winning . . and this is just gravity winning and no opposing forces

Mary: I don't get this though . . . because she [the teacher] said that there were supposed to be two opposing forces

Greg: I know . . on some of them there aren't

Mary: well then . . [inaudible] . . . what's the next one . . . wait . do you guys agree with that

Mark: I sort of do . . because . I was just sitting there . and .. [inaudible] v: you don't think that uh . there's a force other than gravity

Mary: there is . but not in that one

v: oh not in that one . . did you think there was

Greg: well it's not really forcing it up . it's just holding it there

Mary: but do you think it's a force or an agent

v: what do you think it is

Mary: I think that springs is an agent . . it's not really a force . cause it's just sitting there doing nothing . . it's just there

Although still not in agreement with Newton's Second Law, these students are consistent in how they describe the book at rest on the table and the mass suspended from a spring. In both cases they recognize a necessity for a second force but have no means at this time of determining what that force would be. They know about tables and springs but they are not quite sure if tables and springs can cause forces or if they are agents that transmit forces to objects. This limitation in the students' thinking, inhibiting as it is for them, is an indication that conceptual change can not occur until the anomaly of this situation is reconciled. Although these students expressed dissatisfaction with what their conception is capable of explaining, they have no alternative conceptions to consider at this time. The teacher recognized the limitations of the students' ideas to explain these phenomena and responded by introducing the ideas of the scientific community. The patience and restraint she showed in waiting to introduce scientific ideas until the students could "go no further with their ideas' was truly remarkable.

This group of students went on to discuss the same mass on a spring but this time set into vertical motion.

Greg: now what

Mark: bouncing weight

Nancy: it was like the spring and a weight hooked to it . . so whenever you like pull the weight . . the spring pulls the weight . up . and then gravity pulls the weight down . and the spring pulls the weight up . .

Mark: you think that gravity pulls it down . .

Nancy: but then the spring pulls it back up cause . when you pull it down . and then it goes up with the spring and then it comes down with the spring

Mark: I know . what pulls it down

Mary: the spring . when it's tight up the way it pulls it down . . so I don't think gravity pulls it down

Mark: gravity keeps it moving

Mary: well I mean it's already pulling on it . but it doesn't pull it down

Mark: wait . . the suspended weight and then gravity is pulling it . and causing it to go up and down . gravity is pulling on it

Mary: that's what you think

Mark: yeah

Mary: but the spring the spring ha . . you pull it down . and then it goes up cause the spring collects . and then it . but the weight pulls it back down

Nancy: now I see what you are saying

Mark: what's the next one . . do you agree with it everybody

Mary: do you still think gravity pulls it down

Mark: yeah . . gravity is acting on it

Greg: well it might be forcing it a little

s: gravity is acting on it all the time

Mary: yeah but it's not making it bounce up and down

Greg: no the spring is

A common theme running through all of the exchanges between students above is the intelligibility and plausibility of their ideas. Intelligibility and plausibility can be recognized as a sincere desire to know what idea another student is attempting to communicate. Statements of intelligibility are often brief and occur within the discourse in the form of a question of clarification. Frequently statements concerning status were identified by change in the inflection in the speaker's voice as much as by the literal words included in a transcript (Note: At the presentation of this paper the authors showed video tape excerpts of these exchanges between students to emphasize this point). Plausibility statements appear as requests for evidence and typically involve elaboration of the rational components of an explanation.

The following exchange includes a discussion of a ball tossed vertically into the air.

Mary: next one is.. ball toss

s: I got it

Greg: Mark what did we do with ball toss

s's: I have it . . here . . we . . ball toss . . we'll do yours and we'll do ours.

s: OK this is what we have

Mary: can you explain it

Greg: uh well we kind of forgot

Mark: when you throw the ball up . it's stopping and then it's coming down

Greg: we think it's speeding up . and then . slowing down . see it goes up . you let go and then it speeds up and then . let's say at this point it starts to slow down cause gravity gets the bigger effect on it and then it stops and gravity gets a hold on it . and yanks it down

Mary: well here . Greg you mean like goes up . and then when it starts . when the effect of the hand is starting to wear off on it . you mean

Greg: yeah here . . see . throw it up . and then our hand gives this momentum so it speeds up . and then the momentum wears off . so gravity gets a hold of it . and then it goes up to a certain point . and then gravity of it . and then it stops . it comes down really fast . and on the way down it picks up speed until our hand stops it

Nancy: do it . I mean throw it up

Mary: yeah

Greg: you guys agree with that

s: yeah

In this exchange the students are able to provide an explanation of the flight of the ball that is consistent with canonical views. Although the students do not use terminology exactly as a physicist might, they have a sound conception of the motion of this ball. They described several motions in the flight of the ball in a piece wise fashion. They also provide reasons for what forces are acting on the ball--gravity at all times and momentum (which they think of as a force) on the upward path. It should be noted that the teacher did use the term momentum with these students earlier although she did not define the term.

The last exchange analyzed here concerns a ping pong ball struck by a mallet, the ball travels vertically upward.

Mary: but Nancy . what do you mean when it has reached the top

Mark: when it stops

Nancy: I think it stops . . then it goes back down

s: then is it going faster or slower

Mary: well I think that you are hitting it but the hit finally wears off and gravity pulls it down . I don't think that it stops at the top

Nancy: no . after the hit

Mary: you mean when gravity finally gets stronger . than the hit . . OK

Mark: we did the ball toss yesterday . . and it's like the same thing as the ping pong paddle

The explanations these students applied to both the ping pong ball problem and the ball toss problem indicates that they are consistent in reasoning about these phenomena. The ping pong ball struck by the mallet and the ball tossed into the air move in similar ways and have the same explanation of forces acting upon them. These students recognized the similarity of these events and generalized their thinking to include both--an issue concerning the consistency of explanation that the teacher suggested during her directions to the class. These students have developed a fruitful conception of this singular phenomenon. They are capable of describing the vertical motion of any object and of explaining the forces that are acting on that object.

Conclusions:

The students in this classroom did respond to the cognitive demands in this teacher's instruction. They regularly applied the constructs of intelligibility, plausibility, and fruitfulness when discussing force and motion. They also made statements that are indicative of some components of the conceptual ecology--the epistemological commitments of consistency and generalizability were most obvious in the data presented. These students also recognized anomalies in their thinking and the implications these anomalies had for their thinking.

What changed for these students was not only their science content knowledge but their ability to reflect on their thinking. The metacognitive abilities that allowed these students to comment on the status of their conceptions and to provide evidence for their ideas met the cognitive demands of learning in this classroom. Although these students do not have conceptions of force and motion that are in total agreement with canonical views expressed by the scientific community, they demonstrated dramatic changes in the way they discussed and justified ideas related to force and motion. This form of dissatisfaction with existing conceptions is a necessary part of conceptual change learning, and the students in this study clearly did communicate what their conceptions can and can not do for them.

References

Beeth, M. E. (1993). Dynamic aspects of conceptual change instruction and learning. Unpublished doctoral thesis, University of Wisconsin-Madison.

Duit, R. (1993). Research on students' conceptions - developments and trends. In the Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics. Ithaca, NY: Misconceptions Trust.

Hennessey, M. G. (1991). Analysis of conceptual change and status change in 6th. graders concepts of force and motion. Unpublished doctoral thesis, University of Wisconsin- Madison.

Hewson, P. W. (1985). Epistemological commitments in the learning of science: Examples from dynamics. European Journal of Science Education, 7 (2), 163-172.

Hewson, P. W. & Hewson, M. G. A'B. (1988). An appropriate conception of teaching science: A view from studies of science learning. Science Education, 72 (5), 597-614.

Hewson, P. W. & Thorley, N. R. (1989). The conditions of conceptual change in the classroom. International Journal of Science Education, 11 (5), 541-553.

Kuhn, T. (1970). The structure of scientific revolutions (2nd ed.). Chicago: University of Chicago Press.

Lakatos, I. (1970). Falsification and methodology of scientific research programs. In I. Lakatos & A. Musgrave (Eds.), Criticism and the growth of knowledge. London: Cambridge University Press.

Markhews, M. R. (1994). Science Teaching: The role of history and philosophy of science. New York: Routledge.

Posner, G. J., Strike, K. A., Hewson, P. W. & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66 (2), 211-227.

Strike, K. A. & Posner, G. J. (1992). A revisionist theory of conceptual change. In R. Duschl & R. Hamilton (Eds.), Philosophy of Science, Cognitive Science, and Educational Theory and Practice. Albany, NY: SUNY Press.

Thorley, N. R. (1990). The role of the conceptual change model in the interpretation of classroom interactions. Unpublished doctoral thesis, University of Wisconsin-Madison.

White, R. T. & Gunstone, R. F. (1989). Metalearning and conceptual change. International Journal of Science Education, 11 (Special Issue), 577-586.

SE060207

ERIC

U.S. Department of Education
Office of Educational Research and Improvement (OERI)
Educational Resources Information Center (ERIC)

REPRODUCTION RELEASE

(Specific Document)

I. DOCUMENT IDENTIFICATION:

Title: TEACHING FOR UNDERSTANDING IN SCIENCE: WHAT COUNTS AS CONCEPTUAL CHANGE?

Author(s): BEETH, MICHAEL E. AND HENNESSEY, M. GERTRUDE

Corporate Source:

Publication Date: APRIL 1996

II. REPRODUCTION RELEASE:

In order to disseminate as widely as possible timely and significant materials of interest to the educational community, documents announced in the monthly abstract journal of the ERIC system, *Resources in Education* (RIE), are usually made available to users in microfiche, reproduced paper copy, and electronic/optical media, and sold through the ERIC Document Reproduction Service (EDRS) or other ERIC vendors. Credit is given to the source of each document, and, if reproduction release is granted, one of the following notices is affixed to the document.

If permission is granted to reproduce and disseminate the identified document, please CHECK ONE of the following two options and sign at the bottom of the page.

☒ **Check here For Level 1 Release:** Permitting reproduction in microfiche (4" x 6" film) or other ERIC archival media (e.g., electronic or optical) *and* paper copy.

The sample sticker shown below will be affixed to all Level 1 documents

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY

Sample

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

Level 1

The sample sticker shown below will be affixed to all Level 2 documents

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN OTHER THAN PAPER COPY HAS BEEN GRANTED BY

Sample

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

Level 2

☐ **Check here For Level 2 Release:** Permitting reproduction in microfiche (4" x 6" film) or other ERIC archival media (e.g., electronic or optical), but *not* in paper copy.

Documents will be processed as indicated provided reproduction quality permits. If permission to reproduce is granted, but neither box is checked, documents will be processed at Level 1.

"I hereby grant to the Educational Resources Information Center (ERIC) nonexclusive permission to reproduce and disseminate this document as indicated above. Reproduction from the ERIC microfiche or electronic/optical media by persons other than ERIC employees and its system contractors requires permission from the copyright holder. Exception is made for non-profit reproduction by libraries and other service agencies to satisfy information needs of educators in response to discrete inquiries."

Sign here→ please

Signature: Michael E. Beeth

Printed Name/Position/Title: MICHAEL E. BEETH PhD. ASST. PROF.

Organization/Address:
OHIO STATE UNIV.
333 ARPS HALL
1945 N. HIGH ST.
COLS, OH 43210

Telephone: 2-5377

FAX: 2-7695

E-Mail Address: beeth.1@osu.edu

Date: MAY 6 1997