Third Misconceptions Seminar Proceedings (1993)

Paper Title: Insight as the Basis for a Functional Typology of Misconceptions
Author: Moody, David E.

Abstract: The continuing proliferation of studies about student misconceptions is only one of several reasons why a conceptual scheme is in order, a set of categories designed to bring some form and regularity to the record of instances of the general phenomenon. More compelling even than the volume of studies is the need engendered by the search for efficacious forms of instruction. Existing efforts to categorize misconceptions have relied upon the rough and ready framework of the several disciplines. While it may be expedient to distinguish misconceptions in terms of their affiliation with the subject matters of physics, chemistry, and so on, they may also be differentiated on the basis of parameters more strictly pedagogical in nature. What is required, in short, is a functional typology of misconceptions -- functional in the following senses: a typology that (1) attends to the function of misconceptions in the student's conceptual ecology; (2) is designed to facilitate pedagogical purposes; and (3) functions to bring greater coherence to the ongoing stream of research. The psychological construct of insight, it is suggested, may serve as the basis for the development of a typology of this kind.

Keywords: Concept Formation,Theories,Philosophy,Misconceptions,Cognitive Psychology,Abstract Reasoning,Learning Theory,Constructivism,Epistemology
General School Subject: N.A.
Specific School Subject:
Students: Secondary & Elementary

Macintosh File Name: Moody - Insight
Release Date: 10-16-93 A, 11-6-1994 I

Publisher: Misconceptions Trust
Publisher Location: Ithaca, NY
Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics
Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational

Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

----- -----

Insight as the Basis for a Functional Typology of Misconceptions

David E. Moody, Ojai, CA, U.S.A.

In view of the volume of documented instances of misconceptions in the sciences, some recognized set of categories for their classification would seem to be in order. According to Wandersee (1992), the number of published reports in this area now exceeds twenty-four hundred. Reviews of the literature (e.g., Eylon & Linn, 1988; Confrey, 1990) already plead the impossibility of a comprehensive survey of the terrain. In spite of this growth rate, the only operative guide to categorizing misconceptions is the set of boundaries imposed by the disciplines and topics of science. From a pedagogical perspective, such categories have little utility; they provide about as much information as would a classification system for plants based solely on their place of origin.

The absence of a recognized typology for misconceptions in the sciences has several deleterious effects. At the most elementary level, misconceptions are described in the literature with little if any reference to their affinities and dissimilarities with others of their kind. This tendency promotes a spurious sense of uniformity within what is surely a highly diversified set of data.

At a deeper level, the absence of an accepted typology introduces confusion into the substance of research. Muthukrishna, Carnine, Grossen and Miller (1993) have reported evidence that misconceptions, contrary to the consensus view, require no special instructional techniques for their remediation. These conclusions were based on an investigation of instruction in two topics in the earth sciences at the middle school level. Among the multitude of documented instances of misconceptions, what qualities or characteristics of the two selected enabled them to respond so effectively to correction? Or are these two intended to represent the class of misconceptions as a whole? In the absence of a recognized typology, any inferences in response to these questions would be haphazard at best.

Finally, there is the question of the utility of the misconceptions research for practice. The classroom teacher will find it helpful to have something more than a list of topics for which students may hold misconceptions. The teacher may impose an order based upon the needs of the moment, such as the expected frequencies of various student ideas. But of greater lasting value would be a set of categories that arise from the fundamental characteristics of misconceptions. The possible pay-offs for both research and practice, in any case, seem to warrant further investigation.

The objective of this inquiry, then, is to explore the possibility of a functional typology of misconceptions in the sciences. The typology will be functional if it introduces clarifying distinctions into research, and if it offers guidance for the classroom. The categories should also reflect the manner in which misconceptions function in the conceptual ecology of the student.

THE NATURE OF THE COGNITIVE TRANSITION

From a pedagogical perspective, the defining characteristic of a misconception must be the nature or quality of the cognitive transition required to achieve the scientific view. Pines and West (1986) have suggested a metaphor to illustrate this process in its most general aspect. They describe two vines growing toward one another, one from above and one from below, representing the growth in the individual of formal knowledge and informal beliefs. Where the leading tendrils from the two vines meet, there the role of the teacher is to ensure a smooth transition, including the eventual dominance of the formal knowledge. While this metaphor is useful in focusing on the period of transition, however, it does not illuminate the actual nature of that process.

In order to penetrate this crucial aspect of misconceptions, it is helpful to recall that cognition is organized hierarchically and otherwise into structures (cf. Shavelson, 1972; Champagne, Klopfer, Desena, & Squires, 1981; West & Pines, 1985). Cognitive structures are typically held to represent a set of concepts organized according to the perceived relationships among them. Such structures are amenable to display in concept maps, which have often been employed in this way for both heuristic and didactic purposes (Al-Kunifed & Wandersee, 1990). The precise relationship between a given idea, the corresponding cognitive structure, and the resultant concept map is not always entirely clear. Nevertheless, this way of looking at misconceptions highlights a fundamental feature of the transition to the scientific view. That transition, by this logic, does not consist merely in the substitution of one concept for another. On the contrary, what must be replaced is a structured network of relationships among an aggregate of concepts.

Due to its simplicity and universality, the advent of the Copernican understanding of planetary motion provides an elegant example of the foregoing process. The Ptolemaic and the Copernican configurations employ identical conceptual elements: earth, sun, planets, celestial space, and some variety of rotational motion. The transition to the heliocentric idea requires the introduction of no new concept, nor the substitution of one concept for another. Rather, an aggregate of concepts must undergo a reconfiguration in their relationship to one another; a novel arrangement of existing parts is needed, not some new ingredient.

The present argument is not intended to deny that new information or entirely new concepts may be required in order to comprehend the scientific view. Rather, it is to emphasize that understanding often entails a restructuring, reorganization, or redistribution of existing relationships among concepts. If acquisition of the scientific view were merely a matter of incorporating some new piece of information, even if the new information had to displace an existing idea, it would be relatively straightforward. To extinguish a misconception, by contrast, a whole network of cognitive relationships must be dissolved. This feature of misconceptions may also account for students misperceiving a factual event occurring before their eyes (Gunstone & White, 1981). Because they are embedded in a network of meanings in the field of cognition, misconceptions are sufficiently stable to overcome not only standard forms of instruction, but the direct evidence of the senses.

The model of misconceptions drawn in the preceeding paragraphs suggests a similarity with certain principles of Gestalt psychology. According to this school, there is an inherent tendency to organize the perceptual field into patterns, so that the parts of the field are seen as participating in a larger whole. This tendency is made conspicuous in the familiar line drawings and figures that are open to two radically different visual interpretations -- the stairway that flips direction, the vase that becomes two faces in profile, the drawing that can appear either as a young woman standing, or as the close-up of an elderly woman, but neither anything else nor anything in between. These figures represent little more than curiosities in themselves, but they assume a larger significance as metaphors for a certain kind of learning. Such learning is characterized by seeing a new pattern in existing data, rather than by the incorporation of significant new information. Following those who have considered this kind of learning in greater detail (e.g., Kohler, 1947), we will refer to it here as the process of *insight*.

Insight occurs when the student sees, understands, makes sense of a scientific principle, and thereby appropriates it for his own use. It is the moment of "getting it," of "Eureka," of grasping the internal logic or dynamic through which the scientific principle functions and acquires its explanatory power. In its application to the study of misconceptions, insight may be conceived of in terms of the following parameters: (1) a misconception: a set of concepts and relationships among concepts that collectively serve to explain some class of events in the natural world; (2) a scientific view: a similar or corresponding set of concepts rearranged into a new configuration that provides an alternative explanation for the same class of events; (3) the transition from (1) to (2): the psychological, cognitive event consisting of the rearrangement or redistribution of relationships among an existing structure of concepts.

The turning point of the present argument, therefore, is to suggest an essential equivalency between the abstract process of cognitive reorganization and the experiential event of insight. The emphasis upon insight is designed to highlight the magnitude of change and the holistic quality of perception required to achieve the scientific view. Strictly speaking, insight is not a characteristic of the misconception, but rather refers to the moment of understanding of the scientific principle that will supplant the misconception. For the teacher whose task is to extinguish one and ignite the other, however, such a distinction may be academic. Insight is a process that forms a kind of link between two ways of seeing.

If a fundamental feature of any misconception is the kind or quality of insight required to advance to the scientific view, then there exists a criterion for separating false, misleading, or pseudo-misconceptions from the valid instances. For example, consider the naive and scientific ideas regarding what constitutes food for a plant. Because the child considers minerals derived from the soil as part of the plant's food, it has been reported that he is laboring under a misconception (e.g., Smith, Blakeslee, & Anderson, 1993). It is unlikely, however, that any significant cognitive restructuring is necessary in order for the child to adopt the scientific view; he needs only to adjust the boundaries of his concept of food. No actual insight, in short, is required. Accordingly, it seems questionable to consider this notion as a misconception; it is better categorized simply as an item of misinformation.

THE MAGNITUDE OF COGNITIVE CHANGE

There is some reason to believe, therefore, that insight may provide the basis for a functional typology of misconceptions. Insight is a characteristic or quality that arises from the essential pedagogical feature of misconceptions (the moment of transition from the naive to the scientific view), and it has shown the potential to serve as a touchstone to distinguish base metal from gold. The question that remains is what additional categories for classification are suggested by reflection upon insight and its attributes. In order to answer this question, it will be helpful to consider an array of instances:

1. Children's ideas of the earth as an object in space (Nussbaum and Novak, 1976).

2. Students' ideas about the rate of acceleration of falling bodies as a function of their weight (Gunstone & White, 1984).

3. The idea that the seasons are the result of fluctuations in the distance of the earth from the sun during the course of its orbit (Muthukrishna, et al., 1993).

4. The common misconception that speciation is the outcome of changes incurred by the individual organism in its transactions with the environment (Brumby, 1980, 1984; Bishop and Anderson, 1991).

5. The idea that individual atoms display the same macroscopic characteristics (degrees of maleability, variations in temperature) as does the substance of that element (Griffiths & Preston, 1992).

6. The notion that an object constrained to follow a path of circular motion (e.g., a rock at the end of a string) will continue to move in a curved path once the constraining influence is removed or released. (McCloskey, Caramazza, & Green, 1980)

7. The idea that color arises essentially from objects, rather than from the incident light (Feher & Meyer, 1992).

Arranged in the foregoing order -- without regard for distinctions of subject matter, age range, or frequency -- these misconceptions may appear to be on an equal footing. Considered as misconceptions *per se*, however, these notions are subject to sorting on the basis of the kind or quality of insight necessary to overcome them. More specifically, they may be distinguished according to the magnitude of cognitive change, or cognitive distance required to move from the naive to the scientific view. That magnitude or distance will be defined here as the sum of two components. The sheer *quantity* of cognitive restructuring entailed by the transition is the more obvious of these, but it is by no means the only consideration. An additional component, in some cases perhaps the crucial one, must consist of the *quality* of cognitive restructuring -- the unexpectedness, the degree of novelty or surprise, the apparent improbability of the insight in question.

These components are both susceptible to measurement, although in the present context such a step seems premature. Some general observations, however, may facilitate that process. The quantity of cognitive restructuring associated with a given insight could be estimated with a pair of appropriately designed concept maps, representing the misconception and the corresponding scientific view. The degree of similarity between the two maps should be measureable based upon their common and divergent concepts and relationships. If the misconception and associated insight were stated with sufficient precision, an estimate of cognitive restructuring might also be possible without recourse to concept maps. One suggestion for stating misconceptions with that degree of precision is available elsewhere (Moody, 1993).

The quality of cognitive restructuring -- the novelty or unexpectedness of the scientific view -- is an important and sometimes overlooked factor in the study of misconceptions. Those well-schooled in the findings of science may sometimes fail to recall that it is the child's view, not that of science, which typically corresponds more closely with observation and common sense. To the naked eye, the earth is mainly flat, and certainly nothing like a globe. The daily rotation of the sun around the earth appears to be a plain and palpable fact. In general, the scientific view is interesting because and to the extent that it represents a departure from the obvious.

The level of novelty or unexpectedness of any scientific principle is therefore a crucial element in estimating the cognitive distance that must be traversed in order to understand it. The measurement of the level of unexpectedness may defy any simple calculation. Ultimately, however, it should prove possible to obtain a consensus on a scale of unexpectedness, numbering perhaps from 0 to 1, with designated insights associated with certain points along the scale (e.g., the insight into the relativistic equivalency of matter and energy might rank at .90). Other insights could then at least be discussed with reference to a common standard.

The foregoing considerations suggest the possibility of a set of categories designed to rank misconceptions along the dimension of the *degree of insight* required to effect a transition from the misconception to the scientific view. Thus, we may evaluate whether the cognitive distance entailed by the transition to the scientific view reflects an insight of the first, second, or third degree. An insight of the first degree would be one in which both the quantity and the quality of cognitive restructuring falls below some average. An insight of the second degree would be one in which either (but not both) of these characteristics exceeds the average. An insight of the third degree would be one in which both of these characteristics exceed the average. These guidelines are not absolute standards, but rather ways of approximating cognitive distance; they are subject to adjustment according to the individual case.

We now have a basis on which to categorize the misconceptions enumerated previously. The purpose of the following exercise, however, is merely to illustrate how the typology functions, not to make conclusive decisions. Such decisions must await the kind of quantification described above. Present purposes require only a logical analysis of each case.

It is evident in Nussbaum and Novak's work that children undergo extensive cognitive restructuring in order to achieve the concept, and the implications, of a spherical earth. The transition from the evidence of the senses to the abstract image of an enormous globe also constitutes a highly unexpected result. Thus, although it is an achievement which every elementary student takes in stride, the insight required to effect this transition is of the third degree.

To relinquish the notion that objects of unequal weights fall with unequal speeds ought not to entail extensive cognitive restructuring. On the other hand, the scientific fact evidently runs deeply counter to an intuitive sense of the way things ought to work. The insight required to overcome this misconception is therefore of the second degree.

Except perhaps for the student who lives on a farm, it seems unlikely that any explanation for the origin of seasons will be deeply embedded in the fabric of cognition. The only unexpected element in the scientific explanation, moreover, is that the earth's axis of rotation is tilted with respect to the plane of its revolution around the sun. Some minimum level of novelty or unexpectedness, however, is required in order to overcome every misconception; otherwise we are dealing at the level of information. The insight required to understand the origin of seasons is therefore of the first degree.

Students' ideas about the basis for change in the organic world are part of a complex network of notions not unrelated to the child's idea of the process of change generally. The Darwinian explanation for the origin of species, moreover, radically defies common sense: it posits that all of life arose by means of a process that is random, blind, with no plan, goal, or end in view. The insight required in order to understand and appreciate the principle of natural selection, therefore, is evidently of the third degree.

The idea that properties of matter arise from relationships among its constituent parts, rather than inhering within the individual atom, is not widely disturbing to the structure of cognition. The general notion of emergent characteristics is not obvious, but neither is it highly unexpected. In the present context, the level of insight required to attain the scientific view is of the first degree.

Perhaps the idea that an object in motion will continue along a circular path once it is no longer constrained to do so is a vestige of the early inability to distinguish between animate and inanimate matter. The cognitive restructuring required to complete that distinction could be fairly extensive. The idea that the rules governing the motion of inanimate objects differ from those for living things, however, is not unexpected or contrary to common sense. On this basis, an insight of the second degree would be required to overcome this misconception.

The idea that light is indivisible and only serves to illuminate the color inherent in the object is an assumption whose transformation should not require extensive cognitive reorganization. Yet the idea that color in fact inheres in otherwise colorless light is among the most deeply counterintuitive features of ordinary experience. For this reason, the insight required to overcome this misconception warrants designation as of the third degree.

TESTING THE TYPOLOGY

Individuals will differ in their interpretations of particular cases. No system of classification serves all its users with perfect unambiguity. The test of this or any other set of categories is whether it introduces a measure of clarity that exceeds its imperfections. If a proposed typology fails this test, the proposal may nevertheless encourage others to offer a more satisfactory classification scheme.

An additional test of the present proposal might consist of its compatibility with the conditions for conceptual change described by Posner, Strike, Hewson & Gertzog (1982). Those were that the student's original idea should appear defective, and the scientific view should be intelligible, plausible, and fruitful in its explanatory power. The notion of insight may not at first glance appear to correlate well with this four-fold description of events. On the other hand, insight might be considered as the conflation of intelligibility, plausibility, and fruitfulness in a single movement whose outcome we call understanding. In support of this view, it should be recalled that Posner, et al. emphasize that their four criteria are *logical* conditions, with no necessary direct correspondence to psychological or instructional events.

Perkins and Simmons (1988) constructed an argument in some ways similar to the present one. They suggested, as this paper does, that the fundamental pedagogical features of misconceptions are not domain-specific; and they also proposed an alternative system for classifying misconceptions. However, they did so by expanding the range of logical types of misconceptions, rather than by discriminating variable characteristics of the existing arsenal of instances. From a strictly taxonomic point of view, therefore, their observations may have only complicated the current state of affairs.

The present proposal was designed to show in outline form one basis upon which a functional typology of misconceptions could be constructed. A finished classification scheme would introduce further distinctions, and might represent a blend of two or more sets of categories. In any case, much remains to be worked out. To continue to classify misconceptions solely according to content areas and topics, however, will no longer suffice. As a field of study, the misconceptions research has reached a stage of maturity where something more is required -- a set of categories for its data that arise directly from the central issues of the field itself. Those categories will be functional insofar as they embody the essential pedagogical (not curricular) features of misconceptions. If insight does not provide the basis for such a typology, something very like it must take its place.

References

Al-Kunifed, A., & Wandersee, J.H. (1990). One hundred references related to concept mapping. *Journal of Research in Science Teaching, 27*, 1069-1075.

Bishop, B.A., & Anderson, C.W. (1990). Student conceptions of natural selection and its role in evolution. *Journal of Research in Science Teaching, 27,* 415-427.

Brumby, M. (1979). Problems in learning the concept of natural selection. *Journal of Biological Education*, *13*, 119-122.

Brumby, M.N. (1984). Misconceptions about the concept of natural selection by medical biology students. *Science Education*, *68*, 493-503.

Champagne, A.B., Klopfer, L.E., Desena, A.T., and Squires, D.A. (1981). Structural representations of students' knowledge before and after science instruction. *Journal of Research in Science Teaching*, *18*, 97-111.

Confrey, J. (1990). A review of the research on student conceptions in mathematics, science, and programming. In C.B. Cazden, (Ed.), *Review of Research in Education, 16,* 3-57.

Eylon, B.-S., & Linn, M. C. (1988). Learning and instruction: An examination of four research perspectives in science education. *Review of Educational Research, 58,* 251- 303.

Feher, E. & Meyer, K.R. (1992). Children's conceptions of color. *Journal of Research in Science Teaching, 29,* 505-520.

Griffiths, A.K., & Preston, K.R. (1992). Grade-12 students' misconceptions relating to fundamental characteristics of atoms and molecules. *Journal of Research in Science Teaching, 29*, 611-628.

Gunstone, R.F., & White, R. T. (1981). Understanding of gravity. *Science Education, 65*, 291- 299.

Kohler, W. (1947). *Gestalt Psychology*. New York: Liveright Publishing Corporation.

McCloskey, M., Caramazza, A., & Green, B. (1980). Curvilinear motion in the absence of external forces: Naive beliefs about the motion of objects. *Science, 210*, 1139-1141.

Moody, D.E. (1993). Model statements of student conceptions regarding evolutionary change. *Proceedings of the third international* *seminar on misconceptions and educational strategies in science and mathematics*. Ithaca, NY: Cornell University.

Muthukrishna, N., Carnine, D., Grossen, B., & Miller, S. (1993). Children's alternative frameworks: Should they be directly addressed in science instruction? *Journal of Research in Science Teaching, 30,* 233-248.

Nussbaum, J., & Novak, J.D. (1976). An assessment of children's concepts of the Earth utilizing structured interviews. *Science Education, 60,* 535-550.

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,* 211-227.

Shavelson, R.J. (1972). Some aspects of the correspondence between content structure and cognitive structure in physics instruction. *Journal of Educational Psychology*, *63,* 225- 234.

Wandersee, J.H. (1992). The historicality of cognition: Implications for science education research. *Journal of Research in Science Teaching, 29,* 423-434.