Third Misconceptions Seminar Proceedings (1993)

Paper Title: **An Instructionally Oriented Model for Enabling Conceptual Development**

Author: Ebert, Christine & Ebert, Edward S. II

Abstract: As might be expected, instruction in any academic discipline is a matter of making the complex understandable. The usual approach to such a task is to "disassemble" concepts into their component parts, or subconcepts, and to continue doing so until a level of complexity is reached which is commensurate with the intellectual capabilities of those receiving the instruction. The sequence of instruction for conceptual development, therefore, may be considered as resulting from conceptual subdivision on the part of the instructional planner. More often than not, such an instructional sequence is determined by authors of textbook and curriculum materials rather than the classroom teacher. However, effective instruction will frequently require that two conceptualizations be "deconstructed;" the concept to be taught, and the concept already held by the student. The latter, of course, falls squarely within the domain of the classroom teacher to both ascertain and then accommodate.

Keywords: concept formation,educational methods,teacher education,concept formation,misconceptions ,educational strategies,teaching methods,teaching for conceptual change,constructivist teaching
General School Subject: information science
Specific School Subject: elementary science education
Students: elementary

Macintosh File Name: Ebert - Conceptual Development
Release Date: 5-5-1994 G, 11-8-1994 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).

----- -----

An Instructionally Oriented Model for Enabling Conceptual Development

Christine Ebert, University of South Carolina, USA
Edward S. Ebert, II, Coker College, USA

INTRODUCTION

As might be expected, instruction in any academic discipline is a matter of making the complex understandable. The usual approach to such a task is to "disassemble" concepts into their component parts, or subconcepts, and to continue doing so until a level of complexity is reached which is commensurate with the intellectual capabilities of those receiving the instruction. The sequence of instruction for conceptual development, therefore, may be considered as resulting from conceptual subdivision on the part of the instructional planner. More often than not, such an instructional sequence is determined by authors of textbook and curriculum materials rather than the classroom teacher. However, effective instruction will frequently require that two conceptualizations be "deconstructed;" the concept to be taught, and the concept already held by the student. The latter, of course, falls squarely within the domain of the classroom teacher to both ascertain and then accommodate.

Children's science and scientist's science are very similar in their constructivist nature, in that each uses evidence to build an explanation for their observations. A key distinction is that scientist's evidence is objectively derived from observation, while children's evidence tends to be much more subjective. For children's science it may be the case that evidence is derived from observation or it may be that explanations are invented to account for observations. Smith (1991) refers to the influence of interpretive frameworks on the prior knowledge brought to bear by the child in an instructional situation. Indicating the imperative that this issue must be addressed, Smith states, "Learning is not simply a matter of adding new knowledge, or a matter of correcting incorrect information. The prior knowledge includes the interpretive frameworks that the learner uses to make sense of the world and to communicate with other people. It is these interpretive frame works that must change" (p 49). As Ausubel has indicated, what the learner already knows may well be the most important factor influencing learning (1978).

And what the learner already knows is influenced by factors of considerable force other than objective evidence. Children's science, whether demonstrating incorrect, partial, or complete conceptual understanding, nonetheless represents what the child believes to be an acceptable explanation of observed events. Osborne and Freyberg (1985) consider an appreciation of these similarities and differences between scientist's science and children's science to be "of central importance in the teaching and learning of science" (p 13).

The conceptual development model discussed in this paper is based on interviews with children and adults conducted over a period of nearly ten years. It is intended to address the incremental nature of approaching full conceptual understanding while also integrating an appreciation of the child's initial degree of conceptual understanding. The model seeks to arrange the subcomponents of the concept under consideration according to their increasing complexityä and then determine how the student's conceptualization corresponds. In this way, the instructional planner is able to address the four requirements for conceptual change that Posner, Strike, Hewson, and Gertzog (1982) delineate; that dissatisfaction with the prior conception must develop, that an intelligible alternative must be available, the alternative must be viewed as plausible, and that the alternative be viewed as fruitful.

INTERVIEW RESPONSES AND CONCEPTUAL TRENDS

The conceptual development model approaches instruction from two perspectives. Oneä is the content information to be presented, and the other is a determination of what the student already knows. Interviewing provides teachers the opportunity to explore their students' understandings of science concepts. The interview technique helps identify the most appropriate teaching strategies and allows teachers to focus on students' conceptual changes rather than on the concept being taught. This technique promotes an understanding of what a child really believes about a concept and helps teachers learn more about how children think.

Responses from middle school children to the question, "Is an apple alive?" indicate a variety of understandings of the concept of living vs. nonliving. For example, some children will say that apples are not alive because people eat them; others will say apples are alive because they grow on trees; still others say that apples are alive when attached to trees but not alive when picked from trees (Kuehn and McKenzie, 1988).

This range of responses would be considered both typical and appropriate for elementary school students, but teachers of the middle school grades may find them surprising. Without an opportunity to work closely with individual students in a questioning situation, it is difficult forä a teacher to be aware of the variety of ideas children in the same class may hold. Students have little opportunity to elaborate on their answers during typical classroom discussions or question-answer periods. Without the insight provided through direct interviews with students, most teachers tend to accept the assumptions textbook authors make about "average" students' level of understanding. It is important, therefore, that during an interview the teacher should not evaluate the child's responses in terms of correctness or compatibility with an acceptable scientific concept, but rather attempt to establish what the child's ideas are. This technique allows the teacher to identify the personal conceptualization that the child brings to the classroom.

At the University of South Carolina, Kuehn and McKenzie (1988) conducted a study on the advantages of student interviews with 65 elementary and middle school teachers. Teachersä in the project held interviews with their students on two of the following topics: shadows, weather, living vs. nonliving things, and day and night. Teachers used a set of questions that were developed specifically for the interview process. The interviews were specifically intended to allow the child to express his or her own views without being placed in a position of having to defend an answer. In order to accomplish this, questions were designed to elicit the child's perceptions without leading the child toward a predetermined explanation. For example, in the interview on shadows, the teacher might ask, "Can you make a shadow appear where you wantä it to?" After the child responds "Yes," or "No," the interviewer simply asks "Why?" or "Why not?" According to Kuehn and McKenzie, this style of questioning elicits the child's ideas better than using a leading question such as "What would happen if you moved the light source?"

After completing the interviews, the teachers summarized the students responses and reactions to the interview process. Kuehn and McKenzie (1988) list the following as being among the most frequently identified advantages and implications of the interview process:

> The interviews were effective in assessing students' knowledge, ideas, and misconceptions about a concept prior to instruction.
>
> The interview questions encouraged high level thinking and gave students the opportunity to give more complex and lengthy responses than the usual classroom situation allows.
>
> Teachers valued the use of appropriate questions and wait-time to stimulate higher level thinking and creative responses.
>
> Teachers reported an increased awareness of the variety of children's conceptions and abilities, and of the importance of science in the elementary curriculum.
>
> Teachers recognized the importance of focusing on conceptual change in children rather than on the concept itself.
>
> Even though teachers had assured students at the beginning of the interview that there were no right or wrong answers, students from "structured classes" were still concerned about the correctness of their responses (p 22-23).

It may not be possible to interview each student in a class but a wealth of informationä can be gained by interviewing at least four students. Children with varying backgrounds and ability levels should be selected to best represent the diversity of the particular classroom population.

When analyzing the results of the interviews, there are two basic categories of consideration; the classification of responses relative to conceptual development, and the emergence of a group versus individual pattern of understanding. In the first case, the responses given by the children will tend to fall into one of three categories:

1. Correct Understanding - the student's comprehension of the material is sufficient for the concept sought.
2. Incomplete or Partial Understanding - the student understands part of the concept, but is not able to apply his or her understanding correctly in all cases.
3. Misconception - the student's belief is simply incorrect or undeveloped.

Here are examples of responses received from children for each category when using the question, "Is a leaf alive?"

1. Correct Understanding - "When it is green and on the tree it is. When it is all brown and has fallen to the ground it isn't."
2. Incomplete or Partial Understanding - "Well, it grows, but it doesn't reproduce, so no."
3. Misconception - "No, it's just part of a tree."

Obviously, the degree to which the students exhibit each of these categories will determine the design of the eventual presentation. However, the teacher must also consider the patterns of responses from the class as well as specific answers. Though individual needs must not be ignored when a lack of understanding is clearly indicated, planning instruction for the group will require attention to class-wide conceptual tendencies. Once identified, these conceptual tendencies can be compared with a Conceptual Development Model representation of the particular concept under consideration in order to design instruction most appropriate for the particular students involved.

THE CONCEPTUAL DEVELOPMENT MODEL

A concept, as explained by scientists, can be subdivided into a series of smaller, sequential concepts which are important to the complete understanding of the concept. The sequential subdivisions represent partial understanding which would result in incomplete explanations if all of the subconcepts are not incorporated. A generalizable model of this progressive development is illustrated in figure 1.

The first (lower left) cell represents initial conceptualization of the concept which may simply be word recognition. This entry level acquaintance with the concept frequently, but not always, occurs prior to formal instruction. The last (upper right) cell represents the complete understanding of the concept and would be in agreement with accepted scientific explanations. The cells between "initial conceptualization" and "complete understanding" represent the sequentially arranged subconcepts which enable the progressive development of the concept. The

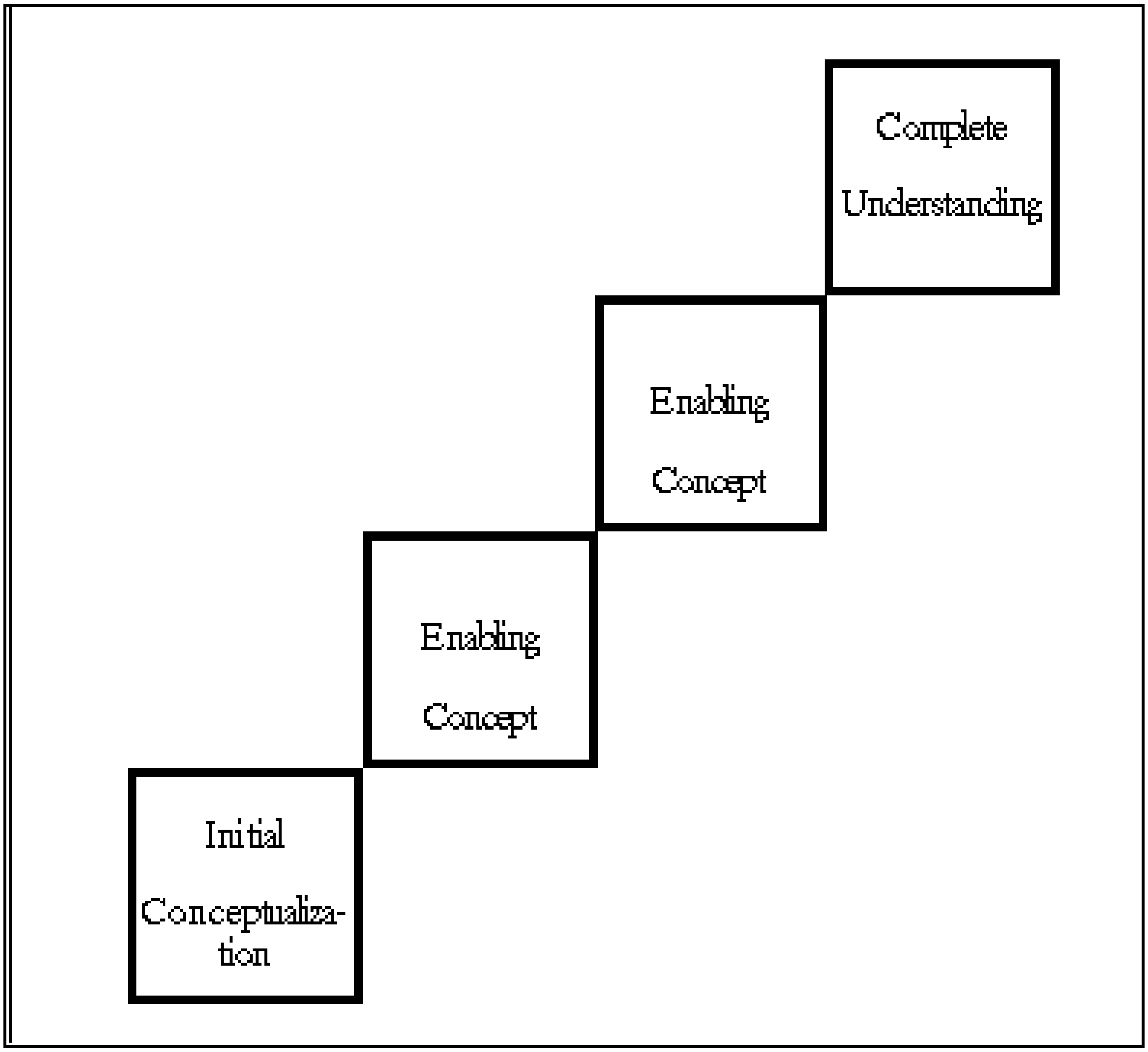

Figure 1. Progression of enabling concepts

enabling concepts are small, vital parts of the whole explanation of the concept. Although figure 1 indicates two enabling concept cells, the actual number varies depending on the complexity of the specific topic or concept.

The topic of *shadows* provides a cogent example and when compared to children's responses serves to clarify the model. The following five responses to the question, "What can you tell me about shadows?" are typical of explanations given by elementary school children.

Mark: "A shadow is something that appears when I go outside."
Sarah: "When I go outside and the sun is shining, I see my shadow."
Brent: "If you have a light, like a flashlight, and you shine it on something, it will make a shadow."
Jose: "If you shine a light on something it will make a shadow on the wall as long as the thing doesn't touch the wall."
Angela: "If you hold something up in front of a light, you will see a shadow on the wall. If you move the object closer to or farther away from the wall, you change the size of the shadow."

The differences in the explanations and complexity of the responses are due to each individual's unique set of experiences. Each student has constructed his/her own explanation and from those explanations it is possible to infer some differences in the experiences. The first two children have probably had experiences limited to first hand observations of shadows in outdoor settings. The other three children have probably had additional experiences when they manipulated light sources and observed the resulting production of shadows.

By way of response to questioning, the authors have found that the initial conceptualization of shadows for many children is that shadows are entities in and of themselves. The explanations sound very much like the portrayal of shadows in the story of Peter Pan. As in Mark's explanation above, a shadow is something that is observable, sometimes, and can be *put away* at other times. Therefore *initial conceptualization* on the model for progressive development of the concept of shadow is labeled *shadow as entity* (see figure 2).

The next step towards understanding of the concept of *shadows* is apparent in Sarah's response which suggests a need for the presence of the individual person and the sun. The shadow is something that belongs to or is a part of an individual and is observable only when the sun is shining. A slight variation of this explanation also requires the presence of the individual and the sun but the sun is considered to be the source of the shadow.

Children who have had opportunities to study or experience shadows in a more objective manner, like Brent, generalize the light source and the object. No longer is the sun the only

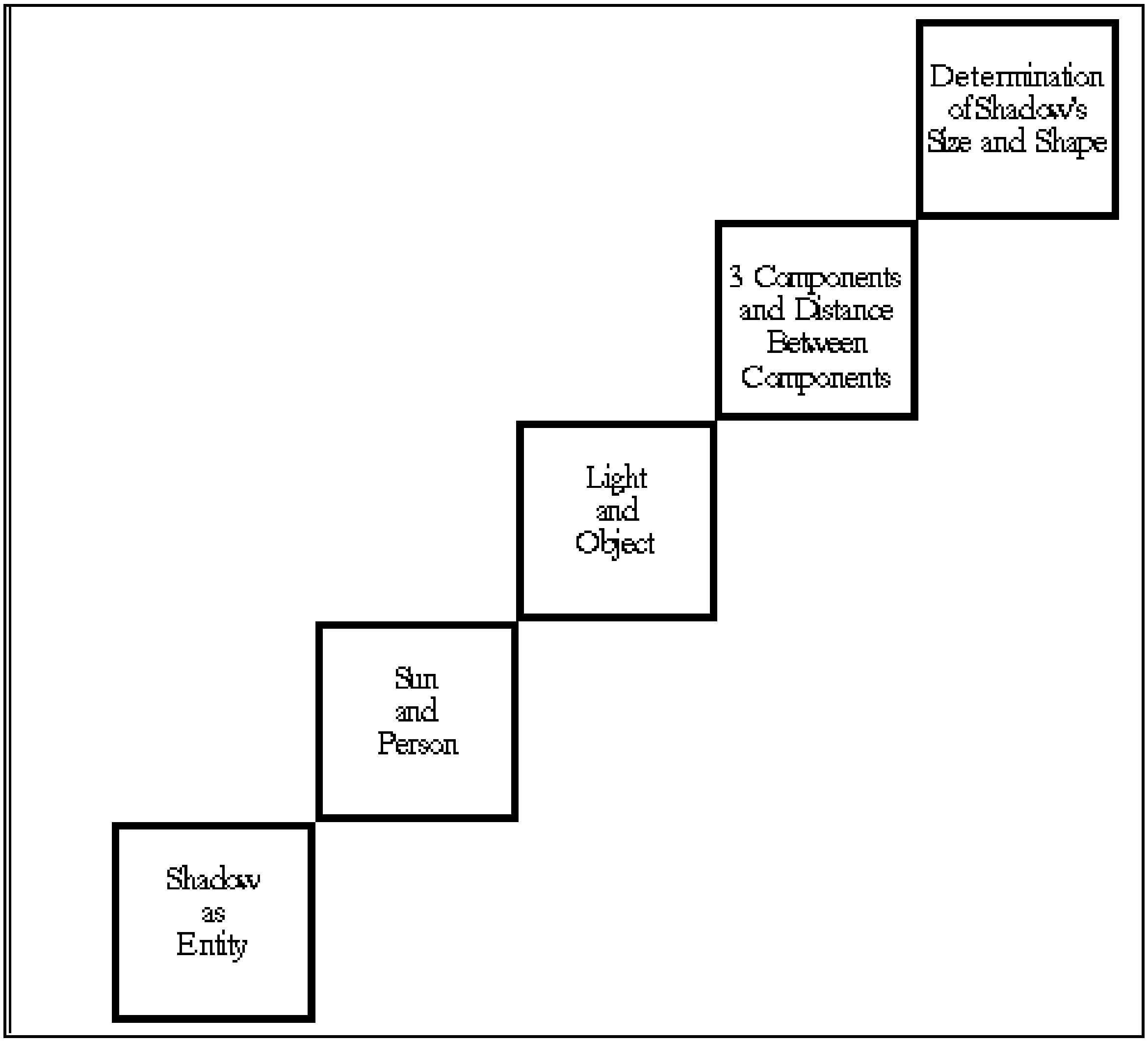

Figure 2. Enabling concepts for *shadows*

possible source of light nor is the person required. Any object can cast a shadow. This generalization is represented in the model by the enabling concept *light and object*. Another enabling concept, *three components and distance*, is noticeable in Jose's response. The fact that there are three components and there must be some distance between those components is vital to the progressive development of the concept.

The more opportunities students have for manipulation of shadows, the more complete the explanations for shadows become. The responses include various light sources, objects, and surfaces upon which the shadow appears. In addition, the explanations, as seen in Angela's response, involve the changing of shape, size, and location. The explanations become quite elaborate, as indeed, the concept is complex. In the model, the complete understanding of the concept is described as *determination of size and shape of shadows*.

The model is incomplete, however, without the addition of necessary information which fosters the progressive development of the concept. The information necessary for one to progress from one enabling cell to another is referred to as a *facilitating concept*. The enabling concepts are outlined in bold lines and the facilitating concepts are indicated by the narrow lines (see figure 3). Let us focus again on the topic of *shadows* (see figure 4). For a child to advance to an understanding of the concept from the notion that a shadow is an entity to the idea that a shadow is the result of the sun shining on a person, the child will recognize two things: 1) the need for the sun and 2) that any person can have a shadow. The order in which these two facilitating concepts occur is not as important as the necessity for both before progress can be made. In order for the child to advance to the third step in the model, two additional facilitating concepts must be understood: 1) the sun can be generalized to any light source and 2) the person can be generalized to any object. Again the order in which the facilitating information is acquired is not important and varies from person to person. Advancement to the next step requires two additional facilitating concepts: 1) shadows have three components - a light source, an object, and a surface upon which it will appear and 2) the distance between the components is important. Progression to the fourth level where a child understands that shadows can vary in size and shape is dependent upon these facilitating concepts: 1) manipulation of the distance between the components will vary the size of the shadows and 2) manipulating the components will change the shape of the shadows.

Knowing the enabling concepts which lead to the progressive development of a concept helps teachers identify the long term and short term goals and instructional objectives. However, it is the facilitating concepts that identify the information necessary for students' development of the concept. Once the necessary information has been identified, teachers can design appropriate experiences which facilitate learning. The facilitating concepts are, therefore, quite useful in curriculum development.

Consideration of the concept *seasons* may serve to further illustrate the dynamics of the

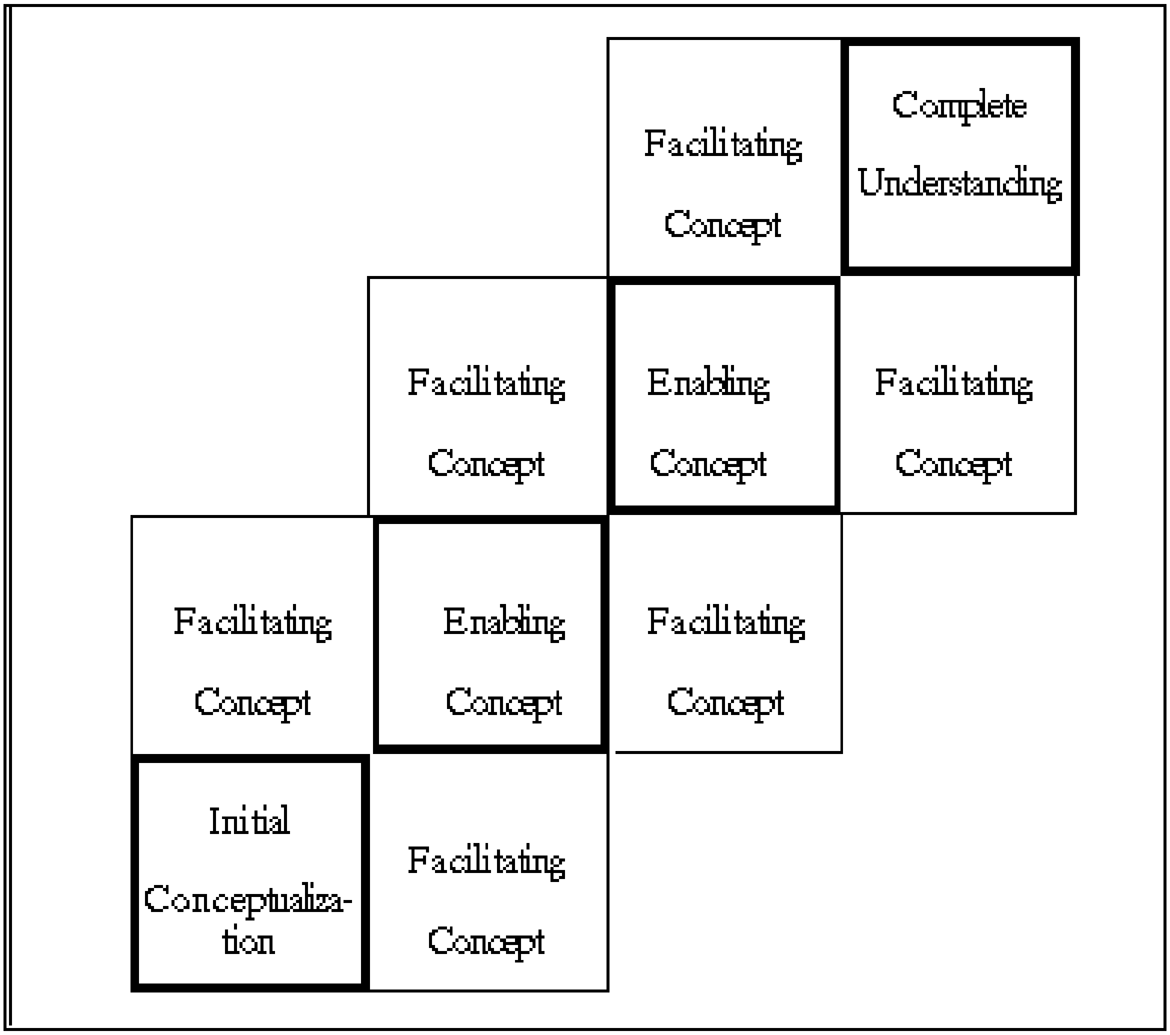

Figure 3. Conceptual Development Model

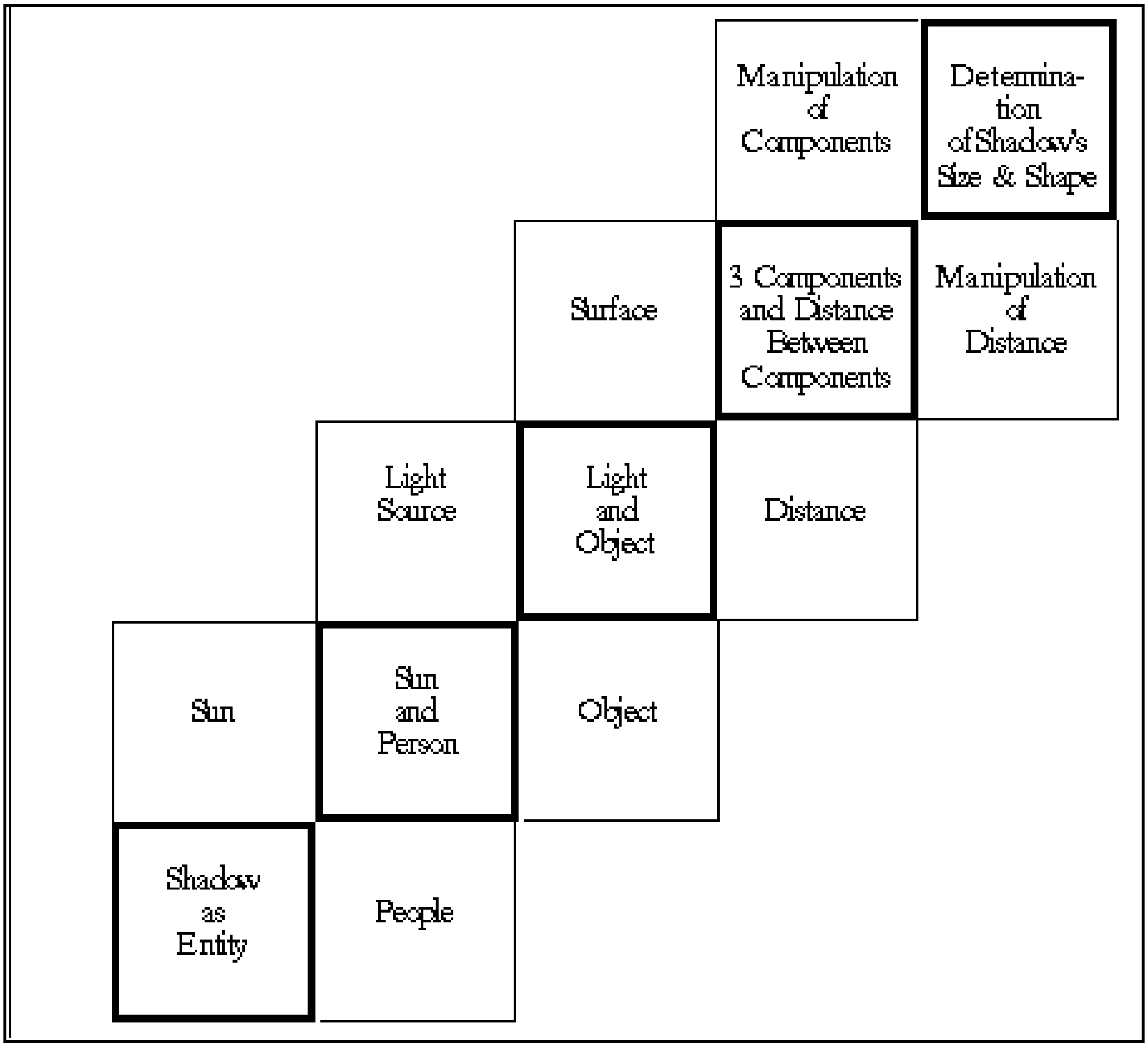

Figure 4. Conceptual Development Model for *shadows*

Conceptual Development Model and provide a better understanding of the importance of facilitating concepts. The series of enabling concepts related to seasons were identified based on the responses gained through interviews with children and adults and an analysis of the subconcepts involved in the scientific explanation of seasons. The conceptual development model for *seasons* shows the progression from the egocentric perspective labeled *recurrence of personal events* to a generalization of *annual events* followed by *characteristics of seasons* and then *relative position of earth and sun* and finally concluding with *understanding of the seasons* (see figure 5).

Schools typically create enriched environments for the understanding of seasons, at least for the first two enabling concepts beyond the initial conceptualization level. A close examination of the facilitating concepts for this topic reveals an abundance of activities found in the elementary curriculum.

The first cell in the model refers to simple word recognition based on an explanation involving the repetition of personally important events. The facilitating concepts: 1) general holidays and events and 2) twelve months are frequently addressed during the first year of schooling. Classroom lessons and activities, bulletin boards, and entire school activities often focus on special events or holidays. Children quickly begin to learn the days of the week and the months of the year.

For children to extend their understanding of the concept to knowing the characteristicsä of the seasons they need information represented by the facilitating concepts cells: 1) weather patterns and 2) plant and animal behavior. Children learn through textbooks the descriptions of seasons, typically northern temperate climate: cold, snowy winters; warm, rainy springs; hot, sunny summers; and cool, crisp falls. Often, children are also taught to make seasonal weather observations relevant to their own locale. In many instances, children spend considerable time collecting weather data, identifying weather patterns, and making local weather predictions.

Many opportunities for studying plant and animal behavior are also found in the elementary curriculum. Some of the topics included in plant studies are: changes in leaves on deciduous trees, life cycles of flowering plants, seed germination and plant growth. Animal activities such as migration, hibernation, estivation, reproductive cycles and changes in coloration are also studied in association with seasons.

Students develop a comfortable understanding of the seasons at this level which may be due in part to the extensive amount of time spent studying the facilitating concepts related to the characteristics of seasons. The comfort may also be due to the fact that these studies are based on directly observable characteristics rather than abstract relationships.

In order to progress from an understanding of seasons based on the characteristics to a

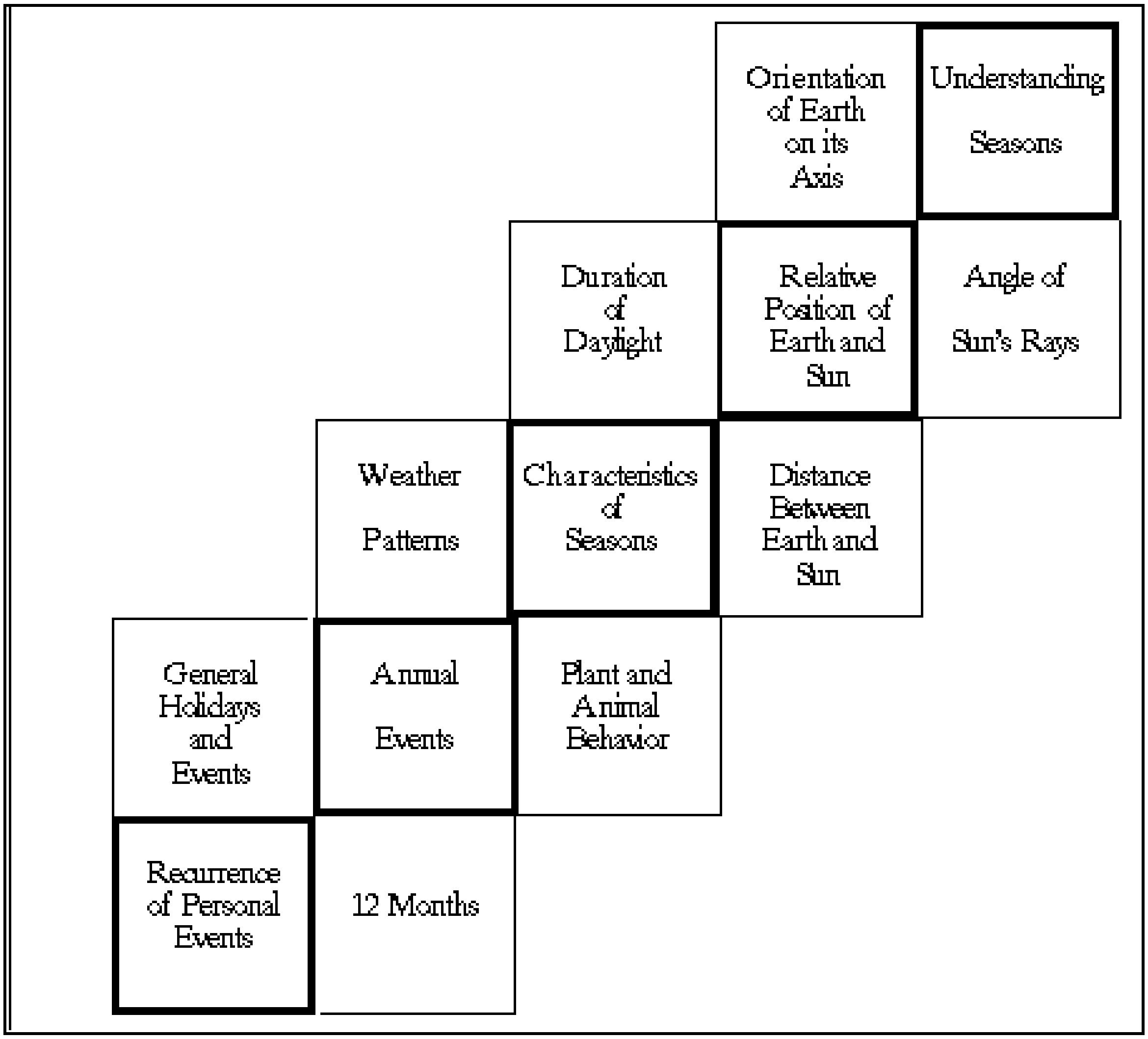

Figure 5. Conceptual Development Model for *seasons*

level of understanding based on the relative position of the sun and earth, it is important to recognize: 1) the duration of daylight varies throughout the year and 2) the distance between the earth and sun. The first of these facilitating concepts is based on directly observable evidence. The other facilitating concept is information based on scientists' observations and is passively accepted by students.

The next set of facilitating concepts is much more abstract: 1) the earth is tilted on its axis relative to a fixed position, the north star and 2) the angle of the sun's rays varies. Very little time in the elementary curriculum is given to the study of these facilitating concepts. Consequently, explanations for the reasons for seasons rarely include this information. More often, explanations for seasons focus on the earth's rotation even though that concept is not one of the enabling or facilitating concepts leading to a complete understanding of seasons. Perhaps, this phenomenon can be explained through the addition of *tangential concepts* to the model (see figure 6).

Tangential concepts are two closely related concepts which share facilitating information. For example, the closely related concept of *day and night* shares facilitating concepts with the concept of *seasons*. For one's understanding of night and day to progress from a mere word recognition of **day** and **night** to an understanding of the concept based on the rotation of the earth, the following facilitating concepts are necessary: 1) identification of a schedule of events which occur each day and each night and 2) the recognition of the duration or length of day, including its variation. It is the second of these facilitating concepts for *day and night* which also serves as a facilitating concept for *seasons*.

Having conducted numerous interviews with children and adults, we find that many people explain that seasonal change is caused by 1) rotation of the earth or 2) rotation of the earth and the tilt of the earth. An examination of figure 6 shows the close proximity of these two concepts when the tangential concepts, *day and night* and *seasons* are aligned by shared facilitating concepts (see shaded cell, figure 6). Many of the children and adults interviewed used and explained rotation of the earth correctly during interviews. Frequently adults and older children will talk about the orientation of the earth on its axis but infrequently do responses include a scientifically complete understanding of that concept. The angle of the sun's rays is a concept rarely mentioned in the explanation of seasons. Perhaps the comfort with the understanding of the earth's rotation and the difficulty with the other more abstract concepts encourages a tangential explanation rather than a continuation along the track of enabling concepts for the understanding of seasons.

In summary, the Conceptual Development Model incorporates **enabling concepts**, **facilitating concepts**, and **tangential concepts**. And from the teachers and curriculum developers perspective the enabling concepts show teachers where to take their students. The facilitating

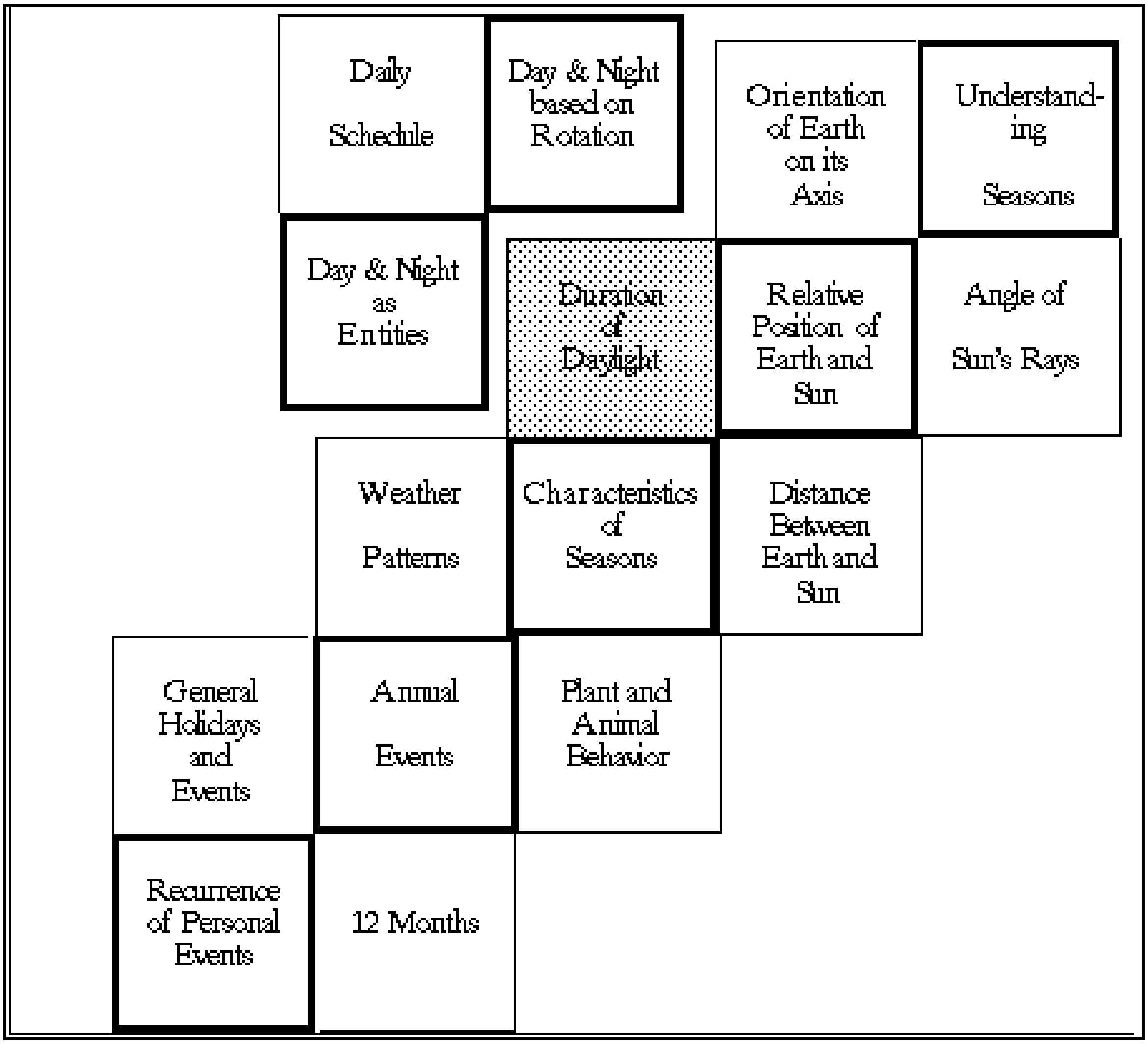

Figure 6. Integration of the tangential concepts *day and night* and *seasons*

concepts tell them how to get there. Tangential concepts, closely related to the topic under consideration, may prove distracting and a source of misconceptions.

Using the various explanations for any topic and keeping in mind the appropriate scientific principles, a model can be drawn to illustrate the progressive development of that concept. Although the model represents the complete development of the concept, it should be noted that for some concepts, the development is still progressing among scientists and therefore the highest cell in the model should be considered tentative and subject to change. It is also important to recognize the appropriateness of the incomplete understanding in the explanations of the concepts prevalent in children's science which can be represented as partial progression along the enabling concepts tracks.

INSTRUCTIONAL APPLICATION OF THE MODEL

Misconceptions and incomplete understandings of concepts can be described in terms of the Conceptual Development Model. Two types of misconceptions can occur. One type of misconception happens when there is a lack of information in one or more of the facilitating concepts at a level lower than the enabling concept level at which the person is attempting to function. The other type of misconception occurs when the student pursues facilitating information and subsequently follows a tangential concept rather than returning to the track of enabling concepts for the original topic. Incomplete or partial understandings of concepts, which occur frequently and appropriately in elementary school children, occur when students learn the enabling and facilitating concepts along the conceptual development track for those specific topics, but the complete understanding level has not yet been attained.

Using the Conceptual Development Model can assist teachers in the search for sources of students' misconceptions. Teachers can use information gained through interviews or other questioning techniques and compare individual responses to the facilitating concepts provided in the conceptual development model for the specific topic. A lack of facilitating information prevents complete understanding at the next enabling level. For example, suppose a student responding to questions about shadows identifies the need for three components: a light, an object, and a surface, but does not recognize that the distance between the three components is important. When asked to do an activity on shadow manipulation or explain how a shadow can be changed, the student is likely to be confused. The student's explanation for varying the size of a shadow may be dependent on 1) the sun and the passage of time or changing the angle of the light, andä 2) the scrunching down of one's body to be small or the standing on tip toes to be large. A comparison of the student's explanation of shadows and the conceptual development model for shadows would reveal a lack of understanding of the facilitating concept that relates to distance. Once the source of the misconception is identified, the teacher can design opportunities for the student to incorporate the missing information.

Without the model or a recognition of the diversity of individual students' understanding of the concept prior to instruction, the typical classroom teacher prepares a series of instructional experiences which assume that all students will begin and end their studies of the topic at the same levels of understanding. The teacher who wants to teach for conceptual change and who is willing to identify students' understanding of the concept prior to instruction, through interviews or some other form of questioning, will identify the diversity of levels of conceptual development which exist and can use the model to determine appropriate instructional experiences for each of the students. Some students may have instructional experiences which focus on a level lower thanä the others while some students may have experiences which focus on a higher conceptual level. This approach to instructional design encourages progression along the enabling concepts track for all students.

REFERENCES

Ausubel, D., Novak, J. & Hanesian, H. (1978). *Educational Psychology: A Cognitive View* (2nd Ed). New York: Holt, Rinehart & Winston.

Kuehn, C. & McKenzie, D.L. (1989). Using interviewing as a teacher education technique. *Journal of Science Teacher Education*, *1 (2),* 27-29.

Kuehn C. & McKenzie, D.L. (1988). The art of the interview. *Science Scope, 11 (5),* 22-23.

Osborne, R. & Freyberg, P. (1985). *Learning in Science: The Implications of Children's Science*. Portsmouth, NH: Heinemann.

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

Smith, E.L. (1991). A conceptual change model of learning science. In S.M. Glynn, R.H. Yeany & B.K. Britton (Eds), *The Psychology of Learning Science*. Hillsdale, NJ: Lawrence Erlbaum Associates.