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Constructivist Strategy for Concept Development Teaching Science in Elementary School

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Abstract

Teaching Science is becoming crucial issue since science is a body of knowledge about nature that represents the collective effort, insight, findings, and wisdoms of human race. The related issues in teaching science need to be examined closely. This paper focuses on exploring how students learn science, Indonesian schools, children's concept development, constructivist view of teaching and learning, and misconceptions and learning. The current findings are still open for further examination and exploration, and further studies are also needed to improve the quality in teaching and learning science.

Introduction

Many children around the world find it difficult to understand science concepts as taught in schools. A steadily growing body of research has promoted a remarkable and problematic picture of student understanding of scientific concepts (Driver, 1983, 1989; Driver &

Oldham, 1986; Linn, 1987).

Students face difficulties in formal teaching of concepts when children are not at a formal stage of reasoning and they need to see concrete models or handle actual objects to truly understand. Nelson (1991) stated an implication of Hall's study was that children are never completely free from misconceptions. Hall's stated appreciation for the "content of a child's mind" was, at best, limited. Following an investigation into children's ideas about fire, Hall described the conception of the sun held by children as "utterly brutish and hopeless" (Hall & Browne, 1903, p. 78). This low estimation of children's power of explanation and interpretation led Hall to advocate the "Nature Study" approach in elementary school science with its emphasis on naming and "object" lessons. According to Smith (1963), Hall indicated that, intellectually, a child should be "considered in terms of his limitations rather than in terms of his capabilities" (p.202)

Nelson cited the studies done by Keuthe (1963) and Rogers (1961) employed large item inventories, requiring written responses, to gauge the level to which high school and college students held misconceptions concerning physics and biology concepts. Both studies identified the specific concepts and natural phenomena that presented the greatest difficulties to the respective age groups. These authors lamented the level of misunderstanding exhibited by these students and suggested that these misconceptions were a result of "memorization that was rote and not in the framework of a logically meaningful system". (Nelson, 1991, pp.21-22)

Studies have indicated that individuals construct informal theories that they use in explaining a wide range of natural phenomena. Often these informal theories have been referred to as misconceptions (Helm & Novak, 1983), alternative frameworks (Driver, 1981), preconceptions/prior knowledge (Hewson, 1982), or children's science (Gilbert, et al., 1982). The terms "alternative conceptions" and "alternative frameworks" were used in this study. This was based on the assumption that prior knowledge is not likely to be considered a misconception by the constructor of the knowledge, but may often be viewed as a misconception by another evaluator. Alternative conceptions have been found to be prevalent in students at various grade levels despite formal teaching in schools. Alternative conceptions that students hold reflect a lack of formal instruction or an inadequacy in the science instruction or curriculum to overcome the students' faulty but self-constructed concepts. Students bring existing, and often misconceived, knowledge of science concepts to the classroom and many teachers are not aware of their student's perspectives nor are they aware of effective ways of handling them (Adenity, 1985). The student misconceptions influence how and what they learn. Rather than creating new information and understanding, existing concepts must be replaced or modified. Thus students' prior ideas about science concepts should be significant to practicing teachers and curriculum developers.

The Condition of Indonesian Schools

Indonesian public schools (grades 1-6, 7-9, and 9-12) use a national curriculum. However, instead of the term national curriculum the Indonesian government currently (2006) promoted the use of national standard on content, process, evaluation, and exit requirement.

Kindergarten classrooms are usually managed as private schools, separated even from elementary schools. Schools follow a national curriculum provided by the government. A spiral curriculum is implemented in Indonesia. For example, the solar system is formally studied in sixth grade and again in the seventh grade and electricity and magnetism are studied in the sixth grade and again in the ninth grade.

Most public schools in Indonesia have very limited funds. Their facilities may differ slightly from one school to the next, but the curriculum is essentially the same. There are minor differences in public schools due to parental and community support which

influences school funding, but it is assumed this will not have a big effect on school achievement.
At the end of 6th, 9th, and 12th grades, students take national standardized tests. These tests are given to measure the degree to which student achievement matches the curriculum goals. The tests cover the concepts taught during the previous grades. Most of the tests are objective tests. The results of the tests are used as screening tools for admission to the next level. Students who get a better grade will gain admission to a "better" school. These tests, which stress content rather than process skills, encourage administrators and teachers to develop teaching strategies, situations and conditions that support student achievement. For example, teachers tested students orally for topics they have been taught on a daily basis. At the end of these tests teachers provide the correct answers, so students memorize the correct answers for specific questions. Therefore, the implementation of the current curriculum and teaching methods tend to be dominated by strategies that emphasize factual and knowledge learning rather than process skills. Schools compete for high scores. Since the general criteria for measuring a "good school" is dependent on the number of students who get high scores, teaching processes tend to emphasize drill rather than provide experience related to the relevant process skills of science.

Although the curriculum (symbolic curriculum) formally emphasizes the development of scientific process skills, in the real world (experienced curriculum), the focus is on content or factual knowledge. With about forty students in each class, lecture is the method used by most teachers. The methods and materials used are also related to public opinion. The community rates the school based on how well students achieve on the national examinations. The higher the average scores in the national tests the higher the public rates the schools. As students move to junior high, and then to senior high, and finally to college a good test score will open the door for the student to a good school. This issue also encourages teachers to give additional tutoring out of school. In some cases this private tutoring is a way for teachers to supplement their income. The parents pay extra tuition for teachers for this tutoring. Some schools also provide general tutoring for all students to prevent complaints from parents who cannot afford to pay for private tutoring. Private tutors for every level are available, especially in big cities.

Children's Concept Development

Regarding children's conceptual development, Vigotsky (1962) proposed three stages: thematic concepts, chain concepts, and true concepts. At the earliest ages, children form thematic concepts, which emphasize relations between particular pairs of objects rather than categorical relations. At the next developmental stage, preschool children form chain concepts. They classify things on the basis of some features, but often change from example to example. Thus the grouping lacks any single defining attribute. Later, in the third stage, children in elementary schools form true concepts, which are based on consistent sufficient attributes.

Chi (1991) proposed that young children categorize things on the basis of thematic rather than taxonomic relations because knowledge is not properly presented. Children's knowledge is contextually bound; it can only be accessed in one context and not another. Developmental changes in the overall structure of knowledge enable children to group things relying on taxonomic relations. Studies propose that concept learning through exemplars plays an important role in conceptual development, especially in younger children. Kossan (1981) reported 7-year-olds learned faster under conditions that have close attention to specific examples than under conditions that need learning of a rule for classifying new examples. On the other hand, 10-year-olds learned well under both conditions. Kossan explained that the 7-year-olds were more correct in the example-based condition because it was closer to the way that they habitually learned. Since children may have difficulty when facing a really new object, they must have some basis of comparison beyond a simple match or not. Children have to develop important features and relations to represent concepts.

Many categories are hierarchical and can be considered at three levels; a general one (the super ordinate levels), the specific one (the subordinate level), and one of middling generality (the basic level), (Rosch, 1976). For example, "bird" is a basic-level category; "animal" is a super ordinate one; and "robin" is a subordinate one.

How do children acquire concepts at different levels of generality? There is no developmental trend for concept development in a specific to general progression or in a general to specific progression. Rather, the possible trend for concept development is that children first learn concepts at an intermediate level of generality and later learn more specific terms through differentiation and more general terms through hierarchic integration (Aglin,1977). Basic-level categories play prominent roles in early conceptual development.

Other studies also revealed that children first learn category names for objects that are familiar and important to them in their daily lives and later learn labels for less familiar and less important objects (Aglin, 1977). This seems to agree with the finding that the frequency of occurrence is the determinant of the order of acquisition of category labels (Abdullah & Lowell, 1981). These researchers investigated the ability of elementary school students to generalize two science concepts, insect and animal, with and without instruction in the form of a mental set. They also found the effects of age, IQ, and sex on the ability of the children to generalize the concepts. The results revealed that age and mental set were significantly related to the ability to generalize the concepts insect and animal. It was found that with age these concepts became more developed and more conceptual in nature. The children in this study were more able to generalize the concept insect than the animal concept. The results suggest that children, with age and instruction, are better able to master a less general concept. The concept of insects is easier than the more general one, animal. The study also showed that children were able to improve their ability to generalize a concept if instruction included a great number and variety of instances and non-instances of the concept.

Constructivist View of Teaching and Learning

In a constructivist point of view, learning is an active process of learners constructing knowledge based on their existing knowledge. Existing knowledge not only influences what is perceived in any situation but also influences how new experiences are interpreted. Hence, knowledge cannot simply be transmitted from teacher to students, but must be actively constructed by each student or learner in their own mind (Von Glaserfeld, 1991).

Furthermore, Lythcott and Duschl, (1990), stated many studies support the constructivist view that (1) children construct their own conceptions about natural phenomena, (2) these conceptions are often different from scientific ones, and (3) children are highly resistant to change toward real scientific views through additional teaching.

A number of studies suggest some strategies that could be helpful in promoting students' conceptual understanding:

- First, providing opportunities for students to make their existing knowledge explicit. In classrooms, students are encouraged to write down or discuss their ideas about science concepts.

- Second, let students confront their existing knowledge, and find the inadequacy of their knowledge. Socratic questioning and peer discussion can help students understand their conceptual conflict, which may make students dissatisfied with their current ideas and hence see the need for new ideas, and third, encourage students to generate a variety of conceptual schemes. When students find existing knowledge is inconsistent, they need to consider possible unifying ideas for science concepts or phenomena, evaluate these for themselves, and eventually reconstruct their ideas in a more coherent way.

- Finally, have students practice the ideas in various of situations.

Meaningful conceptual understanding means that students can apply knowledge in new contexts and make links between concepts or knowledge (Driver, 1985).

Misconceptions and Learning

An essential conception of the constructivist view is that knowledge is actively constructed, and that this process draws on the existing knowledge of the students. Research shows that when teachers do not take students' preconceptions into account during instruction, students understand natural phenomena poorly (Anderson & Smith, 1986; Minstrell, 1984). On the other hand, when teachers learn and take into account how students' preconceptions contrasted with scientific views, they can develop more accurate student understanding of the science concept and improve understanding dramatically (Anderson & Smith, 1986; Eton, 1983).

Not considering students' preconceptions may explain why what is learned is not always what the teacher expects students to learn. Bell (1984) used protocol analysis to investigate how students construct meaning when reading a passage about animals. She found that students integrate the concept of animal through a two-stage process. In the first stage they generate a meaning similar to the author's idea. In the second stage they evaluate the meaning and decide to either accept or reject the meaning. Problems can be encountered in either one of the two stages. Because of their existing knowledge, some students could create incorrect meanings and did not seem aware of the inability.

Students rejected the intended meaning because they either:

1. did not see the need to change their prior knowledge or
2. did not find that the new meaning was more plausible based on their own experiences.

The findings support previous studies (Ausubel, 1978; Osborne, & Wittrock, 1983), which suggest that the existing knowledge of

students played an important role in the interpretation and integration of the instructional material.
Adeniyi (1985) observed a teacher teaching ecology in junior high schools and found that part of the students' problems in learning a science phenomenon can be traced to their preconceptions. After instruction, the students were interviewed about the ecological concepts that the teacher taught in the classroom. The misconceptions were re-stated in the interviews. The students did not replace their preconceptions with what the teacher told them. Old ideas of students prior to instruction are resistant to change and have a profound effect on the understanding of new concepts and generalizations. Again, the existing knowledge of students prior to instruction persists, regardless of instruction (Adeniyi, 1985; Hewson, 1982).

The Clinical Interview as a Method of Eliciting Children's Ideas in Science

The interview as a method of eliciting children's conceptions of natural phenomena and learning in science has won wide acceptance in science education research. While the use of systematic questioning in teaching (such as the Socratic method) has a long history, the interview, as a "professional conversation" (Posner & Gertzog, 1982) was initially developed for use by psychiatrists. Only within the last century has the interview (or clinical examination) become viewed as a tool of diagnosis and therapy. It was this clinical diagnostic technique, as adapted by Jean Piaget, which served as the interview model for much of the later science education research (Milkent, 1977; Novak & Gowin, 1984).

Piaget's development of what was to become known as the clinical interview was prompted by his dissatisfaction with tests and observations as a means of assessing "what conceptions of the world the child naturally forms at different stages of its development" (1929, p.1). Piaget concluded that while tests and observations had the same merit, their shortcomings outweighed their benefits and that the clinical interview melded the best of both methods into a single form. For Piaget, the clinical interview, like a test, was enabling to experimental methods and, like an observation, offered the possibility for interpretation of the child's explanations.

In Piaget's conception of the clinical interview, the researcher begins with the child. When investigating explanations concerning a particular topic, the researcher utilizes questions framed from the comments of children. While the researcher supplies the overall framework of the inquiry, the questions are in the language of children. Piaget urged the use of the verbatim responses of children to avoid possible misinterpretation of their explanations.

In addition, care had to be taken when considering the nature of a particular child's explanations. Piaget offered five levels of explanation ranging from random to reasoned responses. The interviewer had to utilize caution when assigning value to any particular explanation, especially if that explanation may lead to generalizations about an individual or group.

The individual interview has become an accepted technique among those research workers investigating children's ideas about natural phenomena. While interview procedures may differ from study to study, the goal of these interviews seems fairly consistent; that is, "to ascertain the nature and extent of an individual's knowledge about a particular domain by identifying the relevant conceptions that he or she holds and the perceived relationships among those conceptions" (Posner & Gertzog, 1982, p 195). With this unifying goal in mind, it is useful to consider how the individual interview has been used in several of the different research perspectives within the constructivist framework.

Some Related Studies

Previous studies with children's understandings of natural phenomena done by Driver and Erickson (1993) have shown that children do possess "invented ideas" based on experience "which influence the ways in which they respond to and understand disciplinary knowledge as presented in the classroom". Furthermore, it has been found by Driver and Easly (1978) that the identification of these ideas can raise the educator's "awareness of the possible perspectives" held by pupils and can facilitate "more effective communication" between the teacher and the learner.

No more logical method exists to ascertain the complex of student conceptions, regarding a particular phenomenon, than to ask students for their explanations concerning that phenomenon. Individual interviews as "a method of observation, which consists in letting the child talk and in noticing the manner in which his thought, unfolds itself" (Piaget, 1926, p. xiii) have proven a most effective strategy for eliciting such explanations. They provide the desired degree of control for the researcher and at the same time cultivate the interview as a cooperative endeavor between the subject and the researcher (Kelly, 1969, p. 22).

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In the design of the current study, aspects parallel those of previous studies investigating children's conceptions concerning natural phenomena. These shared aspects include: (a) the use of individual interviews to elicit children's explanations, (b) the description of individual explanations of children, and (c) the interpretation and categorization of those explanations.

Several studies have investigated elementary school children's ideas concerning the earth.

Nussbaum and Novak (1976) in An Assessment of Children Concepts of the Earth Utilizing Structured Interview reported part of a continuing series of efforts to design and evaluate an audio tutorial science lesson. The teachers were asked not to supplement the instruction offered. The purpose was to eliminate the teacher as a source of uncontrolled variance in children's concept learning. The subjects were second graders of elementary schools in Ithaca, New York. The basic tasks common to nearly all the assessment items involved predicting directions of imaginary free fall occurring at different points on a model of earth and explaining the prediction.

Furthermore, Nusbaum (1979) in Children's Conception of the Earth as a Cosmic Body: A Cross Age Study studied subjects of grade 4 to grade 8 at elementary schools in Jerusalem, Israel. Instead of using open-ended interviews like in the previous study, he used a multiple-choice format. Each of the four alternative choices was presented with a drawing. He suggested that the interview method should be utilized much more widely in both teaching and research for an assessment of the learning of many other specific science concepts. As was the case with the Earth concept, the interview method would help increase insight of a typical child's conceptual development of selected science concepts generally taught in the elementary schools in Indonesia.

Another study done by Klein (1982), in Children's Concept of the Earth and the Sun: A Cross Cultural Study was designed to assess the understanding of selected earth and solar system concepts of second graders. This study was designed to determine if there are differences in the kind of explanations given in the developmental pattern of the Mexican-American and Anglo-American children in the study. Ericson (1979), in Klein (1982), has emphasized that knowing what the learner "knows" is essential to both teachers and curriculum writers. One of the methods that can be used productively to determine what children know is the interview. In Klein's study, the interview consisted of a series of questions relating to the eight concepts:

1. We live on the earth,

2. the earth is round,
3. the earth is in space,
4. objects appear different from various perspectives,
5. the sun is larger than the earth,
6. night and day are caused by the rotation of the earth,
7. sunrise occurs at different times at different geographical location because of the earth's rotation,
8. the earth makes one complete rotation every 24 hours.

In addition to Klein's study of student's concepts about earth, another study was done by Yuckenberg (1982) using first grade elementary students.

The study focused on children's conceptual understanding of certain concepts of astronomy. The questions were:

1. How big do you think the sun is?
2. How far away do you think the sun is?
3. What does the sun look like to you?
4. How hot do you think the sun is?
5. What would happen if the sun stopped shining?
6. What does the moon look like to you?
7. Tell me something you know about the moon.
8. They say they are going to send a man to the moon in a rocket. What would he have to take with him?
9. What is gravity?

The conclusions were:

1. The astronomical concepts held by the children seem to show that their immediate knowledge had been extended to include many of the concepts held by adults.
2. This study seemed to show that if children already have some information about these concepts, it would seem wise to begin a study of astronomy at an early age. This raises important questions regarding students' understanding of abstract objects in an early development.
3. These children showed a great deal of interest in the sun, the moon,

and the earth.

The more recent study concerning Children's Explanation for Phenomena Related Manned Space Exploration- Gravity, Orbit, and Weightlessness: an Interview Study, was done by Nelson (1991). The subjects of the study were sixth grade students. The main questions of this study answered the following questions:

1. What are the explanations given by individual students to explain the causes and the effects of the phenomena of gravity, orbit, and weightlessness?
2. What explanatory categories concerning gravity, orbit, and weightlessness emerge from analysis of the students' responses?
3. How effective are these identified explanatory categories at capturing the intended meaning of the individual students?
4. What explanatory frameworks concerning gravity, orbit, and weightlessness can be generalized from identified explanatory categories?

Other study done by Dimyati (2001): Sixth Grade Indonesian Student Explanations of Directions on Flat Maps and Globes of the Earth's Rotation to Cause Night and Day, and of the Relative Positions of the Earth, Moon, and Sun During an Eclipse. The purpose of the study was to elicit and analyze sixth grade students' explanations concerning concepts taught in the national Indonesian sixth grade science curriculum. In this study; students were asked to identify the cardinal directions on flat maps and a globe; to describe what causes night and day on the earth; to identify the direction of the earth's rotation; and to identify the relative positions of the earth, sun, and moon during either a solar or lunar eclipse.

The findings in the study can be summarized as follows:

1. Eighty out of 88 students (91%) were able to explain what causes night and day.
2. Approximately 50% could identify the direction the earth rotates to cause night and day.
3. Using a solar system model, about 64% of the students could

describe the relative position of the earth, sun, and moon during an eclipse.

4. Cultural differences affect student thinking. One student thought that Mecca had to be west of everywhere, not just west of Indonesia.
5. The way teachers teach seems to influence student thinking. It is easy for students to form the misconception that up is north. Most maps in classrooms are hung vertically.
6. Some students were confused by the globe. Teachers need to explain why the globe is tilted. Also, they need to help students understand how to determine the cardinal directions on a globe.

Many issues affect students' comprehension in learning science, therefore more research is needed to determine what is needed to help students truly understand these concepts and to determine whether these concepts are best taught at the elementary level.

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