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ABSTRACT

The science learning cycle developed by Robert Karplus and others in the 1960's has been a useful model for many science teachers and researchers. This model stresses the use of structured inquiry to organize knowledge acquisition and problem solving. Recent research in the cognitive science tradition, however, has shown that learning and problem solving are dependent upon more than general reasoning abilities. Intuitive views of the natural world, as seen by children, are often inconsistent with scientific views. These prescientific views must become known to both teachers and students before the correct conceptions can be constructed. The research described in this paper extends earlier research on the process of prediction which has been recognized as a key to determining the value of scientific theories. Included are a summary of the research questions, background information, a description of the pilot study and its results, a description of proposed future research, and a list of 45 references. (CW)

USING PREDICTION IN A SCIENCE LEARNING CYCLE: A PILOT STUDY AND PROPOSED RESEARCH

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RESEARCH QUESTIONS

The science learning cycle developed by Robert Karplus and his colleagues during the 1960's has been a useful model for many science teachers and researchers. This learning cycle has been described by Renner et al. (1976), Karplus (1977), Lawson (1979), and others. It is an instructional model that uses structured inquiry to organize knowledge acquisition and problem solving. Its theoretical base is tied to Piaget's developmental learning paradigm, with reasoning strategies as the focus of interest for most science education researchers. Prior to the 1980's this developmentally-based learning cycle was accepted largely as Karplus and his colleagues had originally envisioned it. Recent research in the cognitive science tradition, however, has made it clear that science learning and problem solving are dependent upon much more than general reasoning abilities. Intuitive views of the natural world that are constructed by young children and adolescents are often inconsistent with scientific views. These prescientific views, referred to as Aristolelian views by diDessa (1982), must become known both to students and teachers before more scientifically correct conceptions can be constructed.

As an important process of science, prediction has long been recognized as a key to determining the value of scientific theories. Just as prediction is an important process in the overall schemes of scientific thought, prediction may be central to the process of helping students gain more accurate conceptions of science. The research described in this paper deals with the following questions:

1. Will students' prescientific concepts (misconceptions) be revealed in a modified learning cycle that uses prediction as the beginning phase?

2. Will students' predictions about common "science systems" (e.g., pendulum, electric circuit) encourage debate and argumentation prior to experimentation?

3. Does a prediction phase in a science learning cycle increase student involvement in exploration and later phases?

4. Can prediction sheets be used by science teachers as an effective tool to assess misconceptions held by students?

5. What factors seem to contribute to effective learning in science learning cycles with and without a prediction phase?

The research described in this paper extends earlier research that explored the process of prediction. Lavoie & Good (1986) looked at the use of prediction by students working with computer-simulated water pollution problems. That study explored students' thought processes and exploration behaviors associated with the process of prediction. This pilot research project and related proposed work will extend the previous study by having realistic classroom settings to assess the effect is of using prediction in a science learning cycle.

In summary, the main goal of this research project is to determine the effects of using a learning cycle, modified to include student predictions about scientific phenomena, in realistic classroom settings.

BACKGROUND AND RATIONALE

As a process of inquiry, prediction has long been associated with scientific thought processes. In a more general sense, Loyle (1979) defined prediction as "a basic human need to arrive at some image of the future in which we have enough confidence to base our actions on" (p. 174). Herber (1978) offers a definition of prediction as "an intellectual or emotional extension of one's knowledge or experience into the unknown, under the constraints of specific conditions or actions" (p. 181). Within the framework of schema theory in reading, Smith (1975) and Nichols (1983) conclude that making predictions about a story or lesson will increase both reading rate and interest, resulting in higher motivation to confirm predicted outcomes. Head Readence (1986) talk of "anticipation" guides in enhancing meaning in reading through prediction. Lipson (1984) showed that when students held inaccurate schema, their text comprehension was interfered with, in that the new text was changed to fit pre-existing ideas.

In science education, the process of prediction was identified by the American Association for the Advancement of Science (AAAS) as one of eight basic processes that should be stressed in science learning. For students in the upper elementary grades, Thiel & George (1976) found that prediction skill develops independent of formal instruction in science.

More recent studies on students' prescientific conceptions (misconceptions) of various natural phenomena emphasize the importance of prediction as a way to assess a students' state of knowledge. A problem or question is posed in the context of a "system" (e.g., pendulum, ecosystem, electric circuit) and the student is asked to predict what would happen if such and such were done to the system. The interview is similar in many ways to the Piagetian clinical interview except that science content is purposely included to assess the nature of prior content knowledge in a specific domain. Most researchers in this area stress the importance of assessing the knowledge state, including misconceptions, of students before instruction proceeds.

Lavoie & Good (1986) explored the nature and use of prediction skills using a computer-simulated water pollution system with high school biology students. They found low initial knowledge, including misconceptions about water pollution, to be strongly associated with unsuccessful predictions. Also, the use of inappropriate independent-dependent variable relationships and lack of persistence were characteristic of the unsuccessful predictor. In addition to conclusions such as these based on their research, Lavoie & Good (1986) suggested the following advantages are associated with a revised learning cycle that begins with explicit predictions about a system that students are about to explore in an inquiry setting:

1. Students are encouraged to organize their existing knowledge of the system to be studied by identifying factors which might affect the system.

2. Students become aware that a variety of opinions are held by fellow students.

3. Prediction usually carries with it a certain degree of commitment to check its accuracy. The act of prediction, therefore, involves both affective and cognitive components of intelligence.

4. Students' predictions can serve as information to the teacher (and student) about what seems to make sense about a system before the system is studied.

5. Progress of students' understanding can be judged more accurately if some type of pretest, in this case a set of predictions, is used as an integral part of the instructional strategy.

The emphasis on the need for students to restructure their ideas about natural phenomena because of fundamental misconceptions is supported by recent research, but there is little agreement on how this restructuring process can be accomplished. Reif & Heller (1982) propose a detailed set of explicit instructions to promote useful knowledge acquistion, Clement (1986) proposes the use of "analogies and anchoring intuitions" to help students reconstruct ideas, Lawson (1986) proposes forms of argumentation as a way to allow students to reveal misconceptions, and others offer a variety of suggestions for science instruction. Proposals by Lawson (1986) and Osborne & Freyberg (1985) support discussion among students about ideas they hold as a prerequisite to changing prescientific beliefs. The prediction phase of a science learning cycle would seem to provide the necessary structure to ensure the required student interaction, prior to experimentation and later phases where formal terms, algorithms, etc. might be introduced.

Holland et al. (1985) in their treatise on induction offer added support to the contention that students with prescienfitic conceptions about causality must confront the inadequacies in their beliefs. They note that inadequate rules are maintained until lack of predictive success triggers inductive changes in the knowledge bank. A learning model that incorporates specific opportunities for predictions, followed by attempts to verify them, should help students recognize inadequacies in their rule systems and provide the motivation to develop more acceptable rules, i.e., where there is a better fit between predictions and outcomes.

Tweney et al. (1980), Karmiliff-Smith & Inhelder (1975), Wason (1960) and many others have found that people favor confirmatory evidence over disconfirmatory evidence. It is clear from misconceptions research that a tendency to confirm existing beliefs will result in many students reinforcing prescientific concepts that interfere with successful problem solving. This is consistent with research in reading by Lipson (1984) and others. Efforts must be made by the science teachers to help students recognize evidence that disconfirms certain long-held beliefs. These efforts might be made easier if prediction were an explicit phase of a science learning cycle.

PILOT STUDY

The teacher-researchers in this pilot study were Faimon Roberts, an eighth-grade science teacher at LSU's Laboratory School, and Greg Moncado, a ninth-grade science and biology teacher at Scotlandville Magnet High School in East Baton Rouge Parish. During the 1987 fall semester, each taught a science class that included a prediction phase as part of the science learning cycle and a class that had the normal three-phase cycle. Figure 1 shows the modified learning cycle used by each teacher-researcher. Other versions of this modified learning cycle have been reported by Lavoie & Good (1986) and Good (1987).

TREATMENT

Each teacher-researcher used his own interpretation of the meaning of "treatment", although there were informal attempts to make the control and experimental treatments uniform. In addition to summer meetings to plan and discuss the project, a video tape of the prediction phase in one of the classrooms was used by the other teacher to help "standardize" that phase of the treatment. Discussions with the teacher-researchers during the fall semester and visits to their classrooms, however made it clear that some important differences existed in instructional strategies. This problem, not uncommon in most experimental studies, will be addressed in a future study described later in this paper.

Prediction sheets, based on studies reported in various journals and monographs, were used by each teacher to assess students' ideas about the science concepts about to be studied (see Appendix A for examples of a prediction sheet). Each student recorded his or her ideas on a prediction sheet and the teacher then led a discussion about the various ideas held by the students. This initial phase of the learning cycle was then followed by a lab that allowed students to test their predictions as well as explore related ideas. It is clear, however, that verification is an important part of the lab phase of this cycle when prediction and discussion precede later phases. The main difference in this and other labs that emphasize verification is that the students are testing their own predictions rather than simply verifying "experts" conclusions.

RESULTS (QUALITATIVE)

Qualitative here means the combined judgments of the teacher-researchers. They were asked to describe their thoughts about the study including general conclusions about the potential of the prediction phase of the learning cycle depicted in Figure 1. What follows then is their description.

Misconceptions play an important role in your classroom. Indeed, students often believe concepts incorrectly, or incompletely. Thus, when a concept is introduced, the teacher is often met with hesitance or complete misunderstanding on the part of the student. Why? Perhaps because what the student has been exposed to does not "fit" his or her own previously learned misconceptions. A teacher sensitive to the prevalence of these misconceptions can include in his or her curriculum methods to dispel myths or virtual untruths.

The object of this study was to include a formal prediction step in the teaching process. This enabled the students to utilize their own preexisting information to develop a possible outcome. The students presented their concepts both orally and in written form. In this manner, the students were committed to one concept, while at the same time aware of many other possibilities. After a discussion of these possibilities, the students were asked to conduct a lab that allowed them to test their own hypotheses as well as those of other students observations and how these observations either supported or did not support their prediction. This method illustrates to the student and teacher the students' misconceptions.

After the initial phase of prediction and lab experiences, content instruction and further lab experiences followed to solidify the students understanding of the correct concepts. The instruction and subsequent lab experiences were constructed with the original answers given by students in the prediction phase in mind. By doing so, students were able to identify their own misconceptions, use what they learning in class, and form correct ideas about their misconceptions.

Our initial research into this method has shown us that when students make predictions and identify what they believe to be the correct answers, they realize their misconception. Consequently, the students release long held misconceptions and naive ideas for more scientifically accurate descriptions.

RESULTS (QUANTITATIVE)

We emphasize at the outset that this is a pilot study, not carried out with the rigor that should be associated with a good experimental study. However, it has provided us with valuable information about the prediction-based science learning cycle and how our future studies should be modified.

Each student in the pilot study completed Misconceptions Identification Tests (MIT) on force electricity, and heat prior to and after studying each concept. Also, each student completed pretests on formal reasoning (Test of Logical Thinking: TOLT) and cognitive style (Group Embedded Figures Test: GEFT).

The Test of Logical Thinking (TOLT) was used to classify students as concrete (intuitive, descriptive, empirical) or formal (reflective, hypothetical) thinkers. Approximately 40% of the students scored 0-1 and were classified as concrete, while 32% scored 3 or above and were classified as formal thinkers.

On the Group Embedded Figures Test (GEFT) approximately 32% of the students scored from 0-6 and were classified as field dependent and 32% scored from 13-18 and were classified as field independent. The correlation between cognitive style (GEFT) and logic (TOLT) was found to be .42.

Each sub-test score (Force, Electricity, Heat) and a total-test score (Total) were analyzed using analysis of covariance with respect to treatment, reasoning ability (Logic) and learning style (Style) (see TABLE 1). No significant differences were detected between the treatment groups on any test score (Force, Electricity, Heat, Total). No significant treatment-by-style or treatment-by-logic interaction effects were noted in the analysis. A significant difference was found due to cognitive style and reasoning ability (Logic) for some of the test scores (TABLE 1).

The Total-MIT score (all subjects) shows a significant difference between those students identified as field-dependent (FDEP) or field-independent (FIND) and a significant difference between those students labeled as concrete or formal. The Force-MIT scores follow this same pattern. However, the scores for the Electricity-MIT show a significant difference between only those students labeled as formal or concrete (Logic) and the Heat-MIT shows no significant difference for either style or logic (TABLE 1).

TABLE 1: ANALYSIS OF COVARIANCE OF MIT-POSTTEST SCORES FOR COGNITIVE STYLE AND REASONING ABILITY (LOGIC) USING PRETEST SCORES AS THE COVARIANT.

	R-SQUARE	ADJUSTED SUM OF SQUARES	F-VALUE	PROB-ABILITY	ADJUSTED POSTTEST MEANS
FORCE-MIT					
STYLE	.33	44.05	24.88	.00	
FDEP					1.61
FIND					2.97
LOGIC	.24	22.05	12.33	.00	
CONCRETE					1.87
FORMAL					2.87
ELECTRICITY-MIT					
STYLE	.19	1.13	1.08	.30	
FDEP					1.82
FIND					2.05
LOGIC	.20	7.21	6.95	.01	
CONCRETE					1.50
FORMAL					2.06

TABLE 1, CONT.

	R-SQUARE	ADJUSTED SUM OF SQUARES	F-VALUE	PROB-ABILITY	ADJUSTED POSTTEST MEANS
HEAT-MIT					
STYLE	.27	.91	1.21	.27	
FDEP					.66
FIND					.86
LOGIC	.32	.39	.64	.43	
CONCRETE					.64
FORMAL					.77
TOTAL-MIT					
STYLE	.47	52.28	13.75	.00	
FDEP					4.19
FIND					5.80
LOGIC	.40	52.28	6.90	.01	
CONCRETE					4.12
FORMAL					5.30

PILOT STUDY CONCLUSIONS

Although the teacher-researchers noted important effects due to the prediction phase of the learning cycle, quantitative analysis of the pre-post MIT data showed no significant differences between the two groups of students. There are many possible explanations for this discrepancy:

1. Teachers were generally unaware of the relative gains made by students in the different classes with regard to their conceptions of science.

2. The MIT's were insensitive to the actual gains made by students with regard to their conceptions of science. Especially the Electricity & Heat tests which contained only four items each.

3. A week or so of instruction on a particular science concept is insufficient time for students to construct new conceptions.

4. The treatments were not defined and implemented well enough for noticeable differences to occur.

5. The nature of the concepts themselves may cause some to be more difficult to address than others.

6. All of the above plus other factors.

It is likely that 5) is the correct choice which means that future research must ensure treatment integrity and use data collection techniques that are sensitive to conceptual growth.

Classroom observations made during the prediction phase of instruction indicate an increase in class participation. There was a noticeable increase in student interaction resulting in some discussion and argumentation. Although it was not widespread there were some who voiced their concerns over the discrepencies between their beliefs and what they found in the laboratory.

Due to the limited amount of preparation time prior to beginning the study there was some confusion between the teacher-researchers as to exactly how the prediction phase of the learning cycle should be conducted. This points out the need for thorough teacher preparation before conducting further studies. This preparation needs to be in the form of teacher workshops and in the production of video teaching tapes that could be used by participating teachers as a review of how the concept should be handled within the learning cycle.

Another important factor that surfaced was the amount of time devoted to each teaching unit. The time spent on some of the concepts was spread over several weeks, due to several factors such as unit design, interruptions, and school activities or a combination of these. The time on task for a particular concept needs to be concentrated within a three- to five-day span. This would allow the students to receive immediate feedback with regard to the testing of their predictions.

The time/interruptions factor in conjunction with test sensitivity (explanation #2) may account for the pattern one sees when viewing the results in the order presented in TABLE 1. The electricity and heat units followed the force unit within the semester. As the semester progressed student responses (e.g., written explanations) on the MIT's were not as robust as they were at the beginning. Therefore, these environmental factors may have overpowered any effect the MIT's were able to detect. Improving the instruments to increase sensitivity should be considered before further studies of this nature are conducted.

Once students have been given the opportunity to test their predictions, the procedures used and the conclusions drawn by the students should be discussed. If students are left alone with no teacher intervention, likely as not, they will find evidence to support their misconceptions making it more difficult than ever to help them reconstruct their ideas. The teacher may need to point out discrepancies in the procedures used or misinterpretations that may have occured. This should be followed by additional activities, if needed, to resolve any inconsistencies that may have occured. In order to reduce the chance of misinterpreting laboratory results these experiences must be carefully selected and tested prior to their use in the classroom. "What experiments would be best suited to teach a particular concept to a particular student?" is another important question that must be answered if we are to alter misconceptions instead of unknowingly lending support to them.

PROPOSED FUTURE RESEARCH

Phase 1

Research on students' prescientific conceptions (misconceptions) usually takes the form of asking for predictions about what would happen to a system (e.g., pendulum, rocket, predator-prey) if one or more variables were changed. McDermott (1984) summarized many examples of these prediction-based studies in mechanics and numerous other studies are found in collections by Driver, et al. (1985), Wenham (1984), Helm & Novak (1983), Osborne & Freyberg (1985) and in most of the major science education journals in the U.S. and abroad. Phase One of the research proposed here would focus on the development and testing of student prediction sheets. The prediction sheets will be based on studies reported by researchers who have investigated science misconceptions held by students at the middle grades (5-9). Each prediction sheet will contain a description of a science system that research has shown is difficult for students to understand because of common misconceptions about the scientific nature of the phenomenon in question. Students will be asked to predict the behavior of some aspect of the system and explain the basis of their predictions. Among the physical science topics that will be used to develop and test prediction sheets are:

1. Conservation of matter - Driver (1985).

2. Electric circuits - Shipston (1984).

3. Light - Guesne (1985).

4. Heat - Erickson (1980).

5. Particulate nature of Matter - Nowick & Nussbaum (1981).

6. Force and Motion - McDermott (1984).

Misconceptions in other science areas are not as well-researched but studies in biology (Fisher, 1983; Wandersee, 1983) and chemistry (Feldsine, 1983; Camacho & Good, 1986) indicate that students' prescientific conceptions are not limited to physics.

Each prediction sheet will be accompanied by information for the science teacher (grades 5-9) to use in administering and interpreting the results of student prediction sheets. For example, a prediction sheet on electric circuits will be accompanied by directions for its use with students in the classroom, an overview of typical results from previous research, and suggestions for how the prediction sheets can be used during the prediction phase of the science learning cycle.

Twenty-five prediction sheets with accompanying information for the teacher will be developed, tested, and revised during Phase One of this project. The resulting product, a teacher's manual for use in conducting classroom research on the proposed modified science learning cycle, will be used during Phase Two of the project. Ten teachers will be selected to assist in the development of the guide and to serve as the teacher-researchers during Phase 2. The 10 teachers will be selected on the basis of interest in and ability to conduct classroom research. A survey is now being conducted (January 1988) to determine the interests science teachers have in various research topics. The results will assist identifying science teachers who are interested in participating as teacher-researchers in this proposed study.

Phase 2

The materials developed and tested for the teacher during Phase 1 will be used during Phase 2, to assist the teachers in their role as teacher-researcher. Prior to the beginning of the 1989-90 school year, a three-day meeting in August will be used to help prepare the 10 teachers for the research project. Among the issues that will be covered are:

1. Research and theory associated with the learning cycle.

2. Research and theory associated with the science process of prediction and how this process will be used in this research project.

3. Results of the pilot research project conducted during the 1987-88 school year.

4. Pretesting to be done in experimental and control treatments.

5. How prediction sheets should be used in the learning cycle.

6. Necessary records to be kept by each science teacher-researcher.

7. Qualitative research techniques that can be used by the classroom science teacher to gather data about student learning in science, including problem-solving progress.

Two teachers per grade level (grades 5-9) will each teach an experimental treatment class and a control treatment class. The experimental treatment will add the prediction phase to the learning cycle and the control treatment will follow the normal three-phase learning cycle as described by Karplus (1977), Renner, et al. (1976), and others.

During the prediction phase in the experimental treatment, the teacher will begin each new concept by distributing a prediction sheet to each student and asking them to make predictions about the system described on the sheet. After they have made a choice and given reasons, the teacher will encourage discussion among students to point out the diversity of opinions about the phenomenon in question. This process is considered necessary by many researchers in order to encourage students to question their beliefs and begin the process of verification through experimentation. During the pilot project conducted in the Fall of 1987 in one eighth- and one ninth-grade science class, each teacher-researcher found that students became quite involved in discussions following the use of prediction sheets. This preliminary evidence suggests that predictions and discussion by students prior to an exploratory phase of a learning cycle increase the motivation to "see who is correct." The research proposed for this project will provide the environment of science classrooms needed to test this hypothesis. The sample of 10 teachers and approximately 600 students should be adequate to allow for conclusions and generalizations that are not possible with the preliminary, pilot research.

In addition to data provided by prediction sheets, pretests and information sheets will be administered for:

1. Demographic information including prior achievement and aptitude;

2. Attitude toward science and science classes;

3. Cognitive style preference;

4. Level of reasoning ability including proportional.

Following administration of pretests in each of the 10 science classes (2 each in grades 5-9), the students in the experimental treatment classes will follow the prediction - exploration - concept introduction - concept application phases of the modified learning cycle while the control treatment students will follow the cycle without a formal prediction phase. It was found in the 1987 pilot study that the prediction phase lasted about one class period, followed by the related lab (exploration) which lasted about one class period. The concept introduction phase consists of a combination of student reports of lab work and discussion, teacher lecture introducing formal terms, algorithms, etc., and textbook and other readings. Finally, during the application phase of the cycle the students solve problems individually and in groups. The problems are intended to help students to better understand the concept(s) in question and extend the ideas to related concepts already a part of students' experience. Following each learning cycle a posttest for science misconceptions will be administered. The test will include the pretest item as well as problems designed to test understanding of the concept in question.

Maintaining the intended treatments in both the experimental and control classes will be helped by using video tapes of the classes in weekly workshops with the teacher-researchers. Since treatment verification is a serious problem in most experimental classroom research, this aspect of the study will be emphasized, especially during the first 4 weeks. Regular classroom visits by the project staff will help to ensure treatment consistency and integrity. Information gained from these visits will be used along with the video tapes during the weekly workshops to refine anything in the treatments that needs attention. Sharing video tapes of classroom sessions during the 1987-88 pilot study was deemed very helpful by the two teacher-researchers, especially in asking questions and using examples or analogies during class discussions.

In addition to the formal pretesting and related quantitative data collected during this semester-long study, qualitative research techniques will be used to provide a more complete picture. The science teacher-researcher will maintain a daily log of comparisons between the experimental and control treatments, with emphasis on apparent effects of the prediction phase on student interest and behavior during the learning cycle. Since the science teachers will be most directly involved in the day-to-day details of the study and should be knowledgeable about student characteristics, interactions, etc. their professional judgments will constitute a very important part of the data base of the study.

The researchers working with the project will visit each classroom at least once each week to observe the various phases of the learning cycle in both treatment and control classes. Their records will serve as a basis to compare with teacher records and video tapes.

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