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ABSTRACT

The overall purpose of this research project was to examine the effects of prediction activities on instructional outcomes in a high school genetics unit. The researcher-developed prediction activities were designed to stimulate student interest and critical thinking prior to formal instruction on the concepts. Enhanced levels of classroom discussion and interaction, higher achievement motivation, positive attitudes toward science, and greater mastery of genetics concepts were identified as the areas of effectiveness being evaluated. Although the quantitative analyses showed no differences between the experimental and control groups, there were apparent qualitative differences. Students in the experimental treatment classes were described as displaying higher levels of interest and participation in the lesson. They were depicted as asking more thoughtful questions, and responding with interest to the challenges presented them while making and defending their predictions. (Author)

Effects of Prediction Activities on Instructional Outcomes in High School Genetics

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Running head: EFFECTS OF PREDICTION ACTIVITIES

Abstract

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Effects of Prediction Activities on Instructional Outcomes in High School Genetics

Since the early 1960's interest has been shown in teaching biology as a process as well as a "body of information" (Self, Self, and Self, 1989). In spite of emphasis on inquiry using the process skills, there is little evidence of implementation in the science classroom (Germann, 1989). In particular the process skill of prediction has been identified as an essential part of scientific inquiry (The National Commission for Excellence in Education, 1983) but it would appear that only a small number of research studies have investigated this process. Lavoie and Good (1988) noted the paucity of research on the "learning, teaching, or thinking processes associated with the science process skill of prediction" (p. 338). There appears to be a need in science education for research in content specific settings which investigates this skill.

The purpose of the present study was to examine the instructional effects of including prediction activities in a high school genetics unit. The aspects of effectiveness evaluated were mastery of genetics concepts, enhanced attitude toward science and achievement motivation, and augmented levels of classroom participation. Genetics was chosen as the domain of research because of the nature of the problems presented. Smith (1989) identified a need for science teachers to effectively integrate subject matter content with problem solving. The prediction activities used in the experimental treatment classes of the present study were developed with such an integration in mind. Manipulation of multiple variables and formal level thinking are often required to understand many of the mechanisms of inheritance, hence this area of biology has been identified as the most difficult by students and teachers (Smith, 1988). Lavoie and Good (1988) believe that predicting is effective when multiple variables are operating. Genetics appears to be amenable to prediction making because of the interaction of these multiple factors.

Both qualitative descriptions and quantitative measures were employed in this study. Each of these research approaches has been called into question because of the "sterile empiricism" of quantitative methods (Rist, 1982), and the lack of validity, reliability, generalizability, and consistency of qualitative studies (Easley, 1977). Quantitative research is described as having much precision, but little scope, whereas, just the opposite is true of qualitative methods (Roberts, 1982). Lawrenz and McCreath (1988) suggested that the former "provide the 'hard' data necessary to document the degree of the effects," while the latter "provide richness to the data" and serve as an intuitive and "valuable source for identifying potentially relevant variables" (p. 406).

The Study

The four-week study was conducted in a metropolitan area of Louisiana during the months of November and December, 1991 in three racially balanced public high schools, each with a student enrollment of approximately 1,200. The research sample initially consisted of 201 biology students but because of attrition and missing data 179 students constituted the final sample. Students were assigned to the biology classes during the scheduling process at the beginning of the school year in August, 1990. Each of the classes was composed of students who were heterogeneously grouped; chi square analysis revealed no statistically significant age, gender, or racial differences between the experimental treatment and control treatment students participating in this study. It should be noted that these schools are part of a system which operates several magnet high schools for academically talented students. Primarily students with medium and low abilities attend the three schools participating in this study because of the removal of the higher-achieving students to the magnet schools. The most recent mean scores on nationally-normed tests for all three of the student bodies were well below the 50th percentile.

Four experienced biology teachers with tenures ranging from 6 to 20 years taught an experimental treatment and control treatment class. To protect the identity of the teachers they will be referred to in the masculine gender and by alphabetical designation (A, B, C, and D). Actually, two of the four teachers were females. They were recommended by their principals to this researcher as effective biology teachers with classroom management skills and good knowledge of subject matter.

Students in the experimental treatment classes participated in 19 researcher-developed (first author) prediction activities prior to formal instruction on the genetics topics. They made written predictions about the patterns and mechanisms of inheritance. The prediction activities used varied formats such as open-ended questions that required explanations for the predictions, multiple-choice responses, as well as genetic crosses requiring the use of Punnett squares. The activities included opportunities for the students to make various types of predictions. Some were content related and required them to respond based on their understanding of specific mechanisms of inheritance. Others promoted thoughtful consideration of ideas; the students were asked to make predictions based on personal beliefs and values. One such opportunity was presented in which student were asked to make predictions about the options that would be available to them if serious genetic diseases were identified in their own family. Still other activities were designed to promote critical thinking.

Following the making of the written predictions, the teachers engaged the students in dialogue about their responses, encouraging them to justify and explain them. The teachers were asked to identify and record any alternative conceptions held by the students by analyzing both their written predictions, as well as their verbal explanations.

The only activities from which the control treatment classes were excluded were the prediction activities used to introduce the genetics topics in the experimental treatment classes. In place of the predictions, the control treatment students usually took notes as the teacher lectured about the topic. The order of the presentation of the genetics concepts was left up to the individual teachers as were the instructional strategies they used to further develop the ideas. The teachers were encouraged to teach the two classes <u>similarly</u> so that the primary variable was the prediction activities used in the experimental treatment classes.

Each of the teachers, because of their idiosyncratic styles, included a variety of activities in their genetics unit, but the experiences were <u>common</u> to both classes. Instruction in the control treatment and experimental treatment classes (following the introductory prediction activities) included multiple strategies such as questioning, the presentation of examples and analogies, guided practice in problem solving, microcomputer simulations, laboratory experiences, and cooperative grouping. The following activities are examples of the varied experiences the students participated in during the genetics unit. Teacher B's students raised three generations of <u>Drosophila</u> and determined the phenotypic ratios for each generation. Students in Teacher A's classes made microscopic slides of <u>Drosophila</u> salivary chromosomes. Teacher C's students raised corn and bean seedlings to compare growth patterns (all factors were controlled except genetic traits). Library reference reports were done by Teacher D's students describing how purebred lines are established in domesticated species.

Quantitative Measures

Identical genetics achievement pre- and posttests were administered to the experimental treatment and control treatment students prior to the genetics unit, and again at the completion of the study. The researcher-developed 20-item multiple-choice test measured the students' mastery of patterns and mechanisms of inheritance. A panel of master biology teachers determined the face validity of the test. Criterion validity was established by the criterion referencing of each test item with the instructional objectives of the state and parish curriculum guides.

Attitude toward science and achievement motivation were also pre- and posttested. Both of the scales used in the present study were developed by Simpson and Oliver (1985). They are composed of short, simple statements to which the students respond using a 5-choice Likert format. The 7-item attitude toward science questionnaire evolved from an original pool of some 30 items piloted and revised in a large study involving 4,000 students in grades 6 through 9, 178 science classes, 57 teachers, and 12 randomly selected schools. The 4-item achievement motivation inventory was developed from an original pool of 12 items. Item reliability was established by Simpson and Oliver at 0.94 for the attitude toward science scale and 0.88 for the achievement motivation inventory.

Another quantitative evaluation was the researcher-developed (first author) Teacher Behavior Inventory (TBI). This measure was adapted from the Virgilio Teacher Behavior Inventory (Teddlie, Virgilio, & Oescher, 1990). The purpose of this quantitative evaluation was to compare and contrast the classroom climate, teacher-student and student-student interactions, lesson development, and teaching style of each teacher during the experimental treatment and control treatment classes.

<u>Qualitative Evaluations</u>

The teachers kept a log qualitatively comparing and contrasting the experimental treatment and control treatment classes on evidence of student interest and involvement in the lesson. Such evidence included participation in class discussions, questioning by the students, their responses to the teachers' questions, argumentation for one's own point of view, and other displays of interest in the topic. The professional judgment of the teachers was an integral part of this qualitative aspect of the study since they were knowledgeable about individual student characteristics. Reliability of these observations was increased by involving the teachers in three training sessions which emphasized making qualitative anecdotal descriptions.

In addition to the teachers' descriptions, independent observers visited each of the four teachers weekly and made qualitative observations using an open-ended format similar to the one used by the teachers in their log. The observers compared and contrasted the experimental treatment and control classes on evidence of student interest and involvement in the lesson.

At the completion of the genetics unit, 16 randomly selected students (eight from the experimental treatment classes and eight from the control treatment classes) were interviewed. Students from the experimental treatment group were asked to describe how they felt about the prediction activities as well as the genetics unit. Those in the control treatment classes were asked questions about their attitude toward the genetics unit. The format for the interviews was the general interview guide approach suggested by Patton (1989). A checklist of relevant topics to be covered served as a guide to insure that common information was obtained.

Interviews were also conducted with each of the four teachers using this same approach. They were asked to describe the effects of including prediction activities in a high school genetics curriculum. Researcher-generated questions arose out of the context of the teachers' responses to the topics identified by the general interview guide.

All of the interviews were audio-taped and later transcribed for analysis.

Results

Qualitative Results

An analysis of the qualitative data indicated differences in the level of classroom participation between the experimental treatment and control treatment groups. Students in the former classes were generally described as displaying higher levels of interest and involvement in the lesson. They were depicted as asking more thoughtful questions and responding with interest to the challenges presented to them while making and defending their predictions. Student participation appeared to be augmented by the prediction activities.

The positive effects of prediction making on student motivation, identified by teachers, students, and observers in their qualitative descriptions, were (a) Interest was enhanced as the students sought to verify their predictions (b) the challenging and thought-provoking nature of some of the activities promoted involvement, (c) the give-and-take dialogue between the teachers and the students about the predictions enhanced attention and interest, (d) even those not wishing to share their predictions evidenced overt displays of participation such as head nodding or eye contact, and (e) the students indicated that many of the prediction activities were fun; they enjoyed sharing their predictions and hearing how the others responded.

The teachers often mentioned in their logs that they were able to identify prior knowledge and alternative conceptions from an analysis of the students' predictions. They believed learning was promoted when these factors were addressed during the lesson(s) which followed.

An analysis of the qualitative data revealed that teaching styles had important effects on instructional outcomes. For Teachers A and B, the observers described positive differences in their teaching between the experimental treatment and control treatment classes. The two teachers were depicted by the observers as probing more deeply in their experimental treatment classes. Teachers A and B asked higher-order more open-ended questions than did Teachers C and D during the discussion of the student predictions.

Quantitative Results

Although the qualitative analyses showed differences between the experimental treatment and control groups, there were apparently no significant quantitative differences for genetics achievement. The descriptive statistics for the pre- and posttests are presented in Table 1. Statistical analysis indicated that students in the experimental treatment and control treatment groups experienced similar success. Table 2 presents the results of the repeated-measures analysis of variance for each of the quantitative measures. Though no statistically significant group effects were shown for genetics achievement, there were significant teacher effects ($p = .0001$) and teacher by time interactions ($p = .0007$). A breakdown of the pre- and posttest least squares means for each teacher is presented in Table 3. Teacher A's students, both experimental and control, displayed statistically significant increases in their

Table 1

Descriptive Statistics for Genetics Achievement Pre- and Posttests

	Control Students (n=82)		Experimental Students (n=97)	
	Pretest	Posttest	Pretest	Posttest
Mean Score (out of 20)	6.594	10.012	6.819	10.100
Variance	5.254	8.939	6.303	11.545
Standard Deviation	2.292	2.990	2.511	3.398
Reliability (KR-20)	0.230	0.534	0.336	0.634
Standard Error of Measurement	2.092	2.189	2 097	2.158
Range of Correct Responses (out of 20)	2-14	4-16	1-15	4-18

Table 2

Analysis of Variance of Major Variables

(TR = Teacher; G = Group; T = Time)

	Genetics Achievement				Attitude Toward Science				Achievement Motivation			
Source	df	SS	F	p	df	SS	F	p	df	SS	F	p
TR	3	376.14	14.42	.0001	3	1209.66	8.56	.0001	3	49.57	0.86	.4631
G	1	[illegible]	0.68	.4093	1	42.36	0.90	.3442	1	0.01	0.00	.9909
TR * G	3	44.49	1.71	.1677	3	18.75	0.13	.9405	3	90.54	1.57	.1983
error a	171	1486.89			171	3286.86			171	8051.09		
T	1	934.32	187.39	.0001	1	8.08	1.05	.3081	1	41.24	12.20	.0006
TR * T	3	89.16	5.96	.0007	3	43.20	1.86	.1377	3	11.45	1.13	.3389
G * T	1	2.65	0.53	.4670	1	25.88	3.36	.0690	1	2.75	0.81	.3683
TR * G * T	3	15.06	1.01	.3912	3	4.26	0.18	.9072	3	4.44	0.44	.7259
error b	171	852.59			171	578.15			171	1321.61		

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Table 3

Least Squares Means of Quantitative Measures by Teacher

	Teacher A (n=52)	Teacher B (n=48)	Teacher C (n=43)	Teacher D (n=36)
Genetics Achievement Pretest (out of 20)	6.62	7.99	5.75	5.97
Genetics Achievement Posttest (out of 20)	11.57	10.93	8.09	8.97
Attitude Toward Science Pretest* (out of 35)	17.25	17.03	17.76	21.91
Attitude Toward Science Posttest* (out of 35)	16.34	16.94	18.59	20.86
Achievement Motivation Pretest* (out of 20)	8.23	8.36	8.80	7.95
Achievement Motivation Posttest* (out of 20)	8.34	9.10	9.74	8.94

Least squares means are reported for all students since no group effects were shown to be significant.

*Lower score is more positive attitude.

genetics achievement scores over time when compared with the other students' scores.

Analysis of pre- and posttest achievement motivation scores revealed no significant differences between the experimental treatment and control treatment groups. Neither were differences found between the teachers, but significant changes occurred over time for both groups (p = .0006) (see Table 2). Although not statistically significant, achievement motivation scores declined during the four-week study for students in all four of the teachers' classes (see Table 3).

No significant differences were found between the experimental treatment and control treatment groups on attitude toward science. Neither were significant interaction effects reported over time, but significant teacher effects were shown (p = .0006) (see Table 2). Teacher D's students had significantly less positive scores for attitude toward science on both the pre- and posttests.

Significantly positive correlations were found between attitude toward science and achievement motivation for both the experimental treatment (p = .0001) and control treatment groups (p = .0014). No such relationships were indicated between genetics achievement and attitude toward science or achievement motivation.

Discussion

Genetics Achievement

The quantitative results did not support the hypothesis that significant differences in mastery of genetics concepts occurred between the experimental treatment and control treatment classes. The teachers expressed disappointment at the overall low scores by both groups on the genetics achievement posttest (see Table I). All stated during the interviews that they were confident their experimental treatment class had a more complete understanding of the genetics concepts because the prediction activities had required the students to think at a deeper level.

Levels of Student Motivation

Maehr (1983) believes that one of the reasons for the poor showing of American science students on international testing may be due to motivational factors. The moderate-to-low levels of achievement motivation reported in this study support that indeed this may be the case. The educators involved in this research effort expressed how discouraged they were about the low levels of motivation that many of their students display. We as science teacher and science educators are forced to ask what are our instructional goals? Are they to disseminate information, or are they to promote the development of thoughtful individuals who can use their knowledge to enhance their lives and those of others about them? The present reform effort in science education favors the latter notion; change is mandated in the present way our science classes are conducted.

The achievement motivation inventory administered in this study asked the students to describe how hard they try to do well in their school work. An analysis of the results indicated that negative (though not statistically significant) effects occurred over time for both the experimental treatment and control treatment groups. Naccarato (1988) noted that quantitative self-report measures of achievement motivation and attitude toward science can be highly susceptible to being influenced by a need of the test taker to respond in a socially-desirable manner. This did not seem to be the case in the present study, for many students indicated low levels for both of these constructs. Perhaps the difficulty of the subject matter combined with the time of the year that genetics was taught (November and December) adversely affected achievement motivation. The results of this study parallel those of Simpson and Oliver (1990). They found that achievement motivation scores declined as the school year progressed.

The finding that Teacher D's students had significantly lower attitudes toward science is noteworthy. He was described by the observers as being very insecure, especially with the prediction activities. Also, his classes were depicted as noisy and complaining. The negative teacher effects shown in this study also corroborate those of Simpson and Oliver's (1990) findings that the environment of the science classroom has a strong influence on attitude toward science.

A noteworthy finding was that attitude toward science was significantly and positively correlated with achievement motivation, yet neither were found to be significantly correlated with genetics achievement for both the experimental treatment and control treatment classes. This is clearly an enigma to this researcher since one would predict that a positive relationship would be shown between attitude and subject matter achievement. Further research is clearly indicated to investigate more thoroughly the relationships between these constructs.

Higher-order Thinking

An analysis of the results of this study indicated that greater emphasis needs to be placed on critical thinking skills in science classrooms. Each of the teachers expressed discouragement at the overall level of their students' thinking competence. Teacher A noted during the interview, "This (critical thinking) is so hard for them. Perhaps they are so accustomed to having information thrown at them and they get what they can." The teachers expressed the belief that their students were not sufficiently challenged to think critically in their former science classes. Therefore, when the students were asked to be involved in prediction activities which required higher-level thinking skills, they felt threatened and some refused to participate. Often heard statements were "This is too hard," or "We haven't ever done this before." The independent observers noted that students in Teacher D's classes sometimes refused to make their predictions; they preferred to wait until the teacher gave them the correct response. A question is raised concerning whether science teachers are hesitant about presenting challenging experiences to students. It would seem that omitting these opportunities compounds the existing problem. The level of questioning is extremely important, and it would appear that the prediction activities enhanced the quality of Teacher A's and B's efforts. This was not observed to any great extent for Teachers C and D. Activities which promote and encourage higher-level thinking <u>must</u> become an integral part of every science classroom.

Teachers A and B were described by the independent observers in this study as "pushing" for critical thinking in the experimental treatment classes. Perhaps there were two reasons for this. First, the students had an opportunity to think through the ideas prior to discussion. Second, since the primary goal of the teachers' efforts was not to disseminate information, it freed them to probe and question at a deeper level.

Prior Knowledge and Alternative Conceptions

One of the most revealing statements during the study was made by Teacher C when he commented, "Most (referring to his students) did not have much prior knowledge except misconceptions." This seemed to be the consensus of the teachers. They stated that the prediction activities assisted them in identifying a number of alternative conceptions held by the students. These identified beliefs seemed to fall into two categories. The first could be characterized as misinformation. For example, some students believed that sickle cell anemia was caused by improper diet.

The second type of alternative conception described by the teachers revealed inadequate use of critical thinking skills. An example of this occurred when students participating in this study had difficulty understanding why germ mutations are generally considered more serious than somatic mutations.

During the interviews, each of the teachers expressed belief that deeper levels of understanding occurred in the experimental treatment classes due to errors in thinking or misunderstandings being dealt with directly and immediately through classroom interaction and dialogue. The importance of identifying alternative conceptions should not be underestimated. Kuhn et al. (1988) contended that the identification of these "inferior strategies" should be given "as much, if not more" emphasis than the instruction that will assist the students in replacing them.

Teaching Styles

An analysis of the data revealed that teaching styles had important effects on instructional outcomes. For Teachers A and B, the observers described positive differences in their teaching between the experimental treatment and control treatment classes. Teachers A and B more astutely used the prediction activities for the purpose they were intended--to promote class participation and critical thinking. It was difficult for Teachers C and D to give up their roles as disseminators of information. Student dialogue was not highly valued in either their experimental treatment or control treatment classes. In spite of four training sessions and numerous conferences while the study was being conducted, the essence of its intent was never thoroughly conveyed to Teachers C and D.

Cooperative Grouping

An important result of this study was the positive treatment effects that occurred when cooperative grouping was used during the prediction activities. The teachers expressed the belief that the prediction activities lend themselves to working within cooperative groups. Teacher A particularly expressed strong feelings that the prediction activities were enhanced if they were done cooperatively. The term he used to describe the effects on students with less confidence was they felt "validated" if they could discuss their predictions within the small group first. Potentially fruitful research is indicated which investigates the effects of combining cooperative grouping and the making of predictions.

Combining Qualitative and Quantitative Research Methods

As in Lawrenz and McCreath's study (1988), the two research methods used in the present research effort revealed somewhat different, yet interesting and relevant information. Significant differences were not found between the experimental treatment and control treatment groups on the genetics achievement and achievement motivation inventories, yet the qualitative descriptions noted remarkable distinctions between the two groups on observable aspects of learning and motivation. Students in the experimental classes were described by the teachers as displaying enhanced levels of understanding. During the times of discussion their elevated interest was evidenced by overt displays of motivation such as volunteering and questioning.

The two research approaches were mutually supportive in describing teacher effects. Both the quantitative and qualitative analyses showed differences between the teachers. In the areas of disparity between the two evaluation approaches further research is clearly indicated.

By combining the two methods, a much clearer picture was made of the strengths and weaknesses of the experimental treatment. Although the two approaches were not always mutually supportive, they each added unique dimensions which would not have been described unless both had been included.

Final Thoughts

One of the most heartening aspects of this study was the intention of all four of the teachers to include the prediction activities in their future genetics units and prediction making in their repertoire of instructional strategies. They expressed regret that the activities could not be used in their control treatment classes. On one occasion, Teacher D resorted to using the prediction activity "Crossing-Over and Other Chromosome Mutations" when students in the control treatment class were experiencing difficulty understanding these concepts.

The teachers stated that the requirement for students to think critically as they made their predictions was one of the most positive effects. Teacher B commented during the interview, "I had gotten into the old habit of asking questions and giving them two or three seconds to respond and then moving on. I think by having them make the predictions they have to come up with an answer instead of saying, 'I don't know.'" Teacher D stated, "I have already started doing it in other classes. I ask them to predict to get them thinking about it."

Another noteworthy finding from the triangulated qualitative and quantitative data was that for both genetics achievement and attitude toward science, significant teacher effects were found. The teacher does seem to make an important difference in the level of learning and the development of positive attitudes in the science classroom.

Madsen and Madsen (1983) recommended that teachers vary their classroom activities to include innovative and fun experiences to promote learning. A summary of the qualitative data from this study indicated that making pre :tions promoted classroom participation, critical thinking, and student enjoyment. As Mathison (1989) noted, attitude affects personal involvement in a task. Assisting students in developing a positive and anticipatory "mind-set" toward an assignment appears to hold promise for increasing student motivation and the quality of learning.

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