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ABSTRACT

Science fairs are held in many elementary, junior high, and high schools. Typically they are thought of as a competitive event where students display science projects. Publications occasionally print accounts of successful science fairs, but these articles are usually based on opinions rather than on research. The purpose of this study is to report desirable characteristics of a school science fair according to available research. The characteristics include: (1) type of project to be entered in the fair; (2) determination of students who should participate; (3) relative merits of competitive or noncompetitive fairs; (4) value of working individually or in groups; (5) motivators offered; and (6) amount of work expected to be done outside of the classroom. The document includes the summaries of 35 articles and a glossary. Several recommendations are stated: students should do experimental projects; students of all grade levels should participate; competition with clear goals can be an effective motivator in science fairs; the most effective structures include cooperative student projects; and better quality projects can be expected when children work on them outside of the classroom. (CW)

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Establishing the Goals of a Science Fair

Based on Sound Research Studies

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Introduction

Statement of Problem

Science fairs are held in many elementary, junior high, and high schools. Typically they are thought of as a competitive event where students display science projects. Teacher education publications occasionally print accounts of successful science fairs, but these articles are usually based on opinions rather than sound research. The purpose of this study is to determine the characteristics that a school science fair should have based on sound research. The characteristics to be determined are: 1) the type of project to be entered in the fair, 2) the determination of students who should participate, 3) the relative merits of competitive or non-competitive fairs, 4) the value of working individually or in groups, 5) the motivators offered and 6) the amount of work expected to be done outside of the classroom.

Limitations of the Study

Research of science fairs is extremely limited. Those studies that do exist are usually surveys of the winners to determine the characteristics of the winners. While even opinion articles are not abundant, they usually center on the logistics of organizing a science fair and offer a variety of unfounded advice about the type of project to accept and the desirability of the competitive atmosphere.

Since sufficient science fair research could not be found, it was necessary to break down the science fair into its components and consider research from a variety of disciplines. The components determined to be applicable were: inquiry as a goal for learning science; teaching scientific inquiry; instructional goal structures; motivational structures; and working outside of the classroom.

Purpose of the Study

The purpose of the study was to gather sound research associated with the components of a science fair that together make a science fair a unique learning structure. By determining the best combination of these components, the likelihood of effective teaching can be improved.

Organization of the Study

Within the introduction can be found a glossary of terms of which may be beneficial to the reader. Following the introductory material are brief annotated bibliographies of research articles applicable to science fairs. A narrative summary of the research follows the annotations, followed by a compilation of the facts in the conclusion. The annotations, summary, and conclusions are all divided into the categories of inquiry as a goal for learning science; teaching scientific inquiry; instructional goal structures; motivational structures; and working outside of the classroom. Following the conclusion, recommendations for science fairs can be found based on the collection of research studies reviewed.

Glossary of Terms

advanced organizers- complex and deliberately prepared sets of ideas which are presented to the learner in advance of the body of material to be learned, in order to insure that relevantly anchoring ideas will be available (Ausubel, 1969, p. 145).

Ausubel's Cognitive Theory- the human nervous system is regarded as a data processing and storing mechanism so constructed that new ideas and information can be meaningfully learned and retained only to the extent that they are relatable to already available concepts or propositions which provide ideational anchorage (Ausubel, 1970, pp. 10-11).

award- a device used to stimulate, reinforce, or reward initiative; may be verbal or material (Good p. 54).

cognitive conflict- a means of mental development where the essential act in learning is not the coordination of behavior with external events but rather the coordination among activities within the mental structure (Bredderman p. 189).

compatible with personal goals- attaining the outcome does not require the student to become competent in a behavior or activity which is incompatible with his or her long-term personal goals (Welch et al. p. 43).

competitive learning structure- students are told that their goal is to learn the material better than the other students in the group; they should not discuss their ideas with other students and should study independently (Okrbukola and Ogunniyi p; 879).

concept- a class of entities that have the same relevant or defining characteristics (Cantu and Herron p. 135).

cooperative learning structure- the students are told that their goal is to learn together; they are to share and help each other understand the material; they should discuss and list their ideas together and make decisions by consensus, and they should seek help and assistance primarily from each other rather than from the teacher (Okebukola and Ogunniyi p. 879).

didactic teaching- a teaching method where the teacher presents facts and ideas that the students are expected to record, store and retrieve (Tjosvold p. 282)

ecological consistency- not demand(ing) a student behavior or activity which environmental conditions in a school or community do not allow (Welch et al. p. 43).

fair-*an exhibition, often competitive, of farm, household, and manufactured products or of international displays, usually with various amusement facilities and educational displays; (* indicates that this particular definition has its origin in the United States) (Guralnik p. 502).

group competition- rewards are differentially allocated among groups according to their relative performances, and group rewards are typically allocated equally within each group (Michaels p. 88).

group reward contingencies- the performance of each group is independently compared with a previously established standard to determine reward allocations to each group, and group rewards are typically allocated equally within each group. Rewards are unrelated among groups, but positively related among individuals within groups (Michaels p. 88).

individual competition- rewards are differentially allocated among individuals according to their relative performances. Rewards are negatively related among individuals (Michaels p. 88).

individual reward contingencies- the performance of each individual is compared with a previously established standard to determine reward allocation to each individual. Rewards, therefore, are unrelated among individuals (Michaels p. 88).

individualistic learning structure- students are instructed to work on their own, avoiding interactions with other students, seeking help and assistance from only the teacher, working at a self-regulated pace, and completing as much of the assignment as possible.(Olebukola and Ogunniyi p. 879).

inquiry teaching- a teaching method that requires active student participation and attempts to help students examine, investigate, and explore questions and situations and to discover their own insights and understanding. The emphasis is on learning principles, concepts and problem-solving skills rather than learning factual information and subject matter. Students are asked to experience how scientists themselves discover and create knowledge (Tjosvold p. 281).

laboratory activities- contrived learning experiences in which students interact with materials to observe phenomena. The contrived experiences may have different levels of structure specified by the teacher or laboratory handbook, and they may include phases of planning and design, analysis and interpretation, and application as well as the central phase. Laboratory activities are usually performed by students individually or in small groups, and does not include large-group demonstrations, science museum visits or diffused field trips (Hofstein and Lunetta p. 202).

motivation, extrinsic- motivation which stems from positive or negative reinforcements which are external to the behavior itself rather than inherent in it; studying to get good grades not because the study is enjoyable (Wolman p. 243).

motivation, intrinsic- motivation as an incentive which originates within the behavior itself rather than externally as in playing a musical instrument for enjoyment (Wolman p. 243).

Piagetian intellectual development model- there are a few general guidelines which will be useful:

1) From birth until intellectual development reaches its zenith, the human being has the potential of sequintially utilizing four distinctly different types of thought during a lifetime.

2) The quality of thought for each stage is different from the preceding and succeeding stages. In other words, what the individual believes to be true about the world and how he utilizes those thoughts is different from stage to stage.

3) The succession through the stages is invariant--one does not skip a stage--but the age at which any one individual enters a particular stage depends upon his individual characteristics (Renner, et al. p. 217).

practical skills- designing and executing investigations, observing, recording data, analyzing, and interpreting results (Okuebukola and Ogunniyi p. 875).

pseudoexamples- perceptible entities that are used to focus attention on critical and variable attributes of an abstract concept in the same way that real examples and nonexamples are used to teach the attributes of concrete concepts (Cantu and Herron p. 136).

psychological consistency- not demand(ing) a behavior or activity which the student's developmental, intellectual, and/or personality characteristics do not allow him or her to perform (Welch et al. p. 42).

reward, extrinsic- a reward which is external to the behavior being rewarded or which is perceived by the subject as not being logically or intrinsically connected to the thing being rewarded (Wolman p. 327).

reward, intrinsic- a reward which is closely connected to or part of the behavior or task being rewarded and cannot be separated from it (Wolman p. 327).

science fair- 1) a collection of student exhibits, each of which is designed to show a biological, chemical, physical, or technical principle, a laboratory method, or some procedure for industrial development (Good p. 577).

science process skills- that set of skills that scientists use to solve problems (Yeany p. 279).

scientific inquiry- a subset of general inquiry concerned with the natural world (Welch et al.).

stage of development, concrete operations- according to Piaget, the period in the child's mental development from preschool through upper elementary grades (about junior high school) in which analysis of situations and events is based largely upon present perceivable elements (Good p. 553).

stage of development, formal operations- according to Piaget, the final stage in mental development of the child in which he is able to use symbols and deal with abstractions (Good p. 553).

teaching and learning by inquiry - getting first-hand experience in doing science and, in addition to developing inquiry skills, such as the abilities to identify and define a problem, to formulate a hypothesis, to design an experiment and to collect, analyze, and interpret data (Tamir, 1983 p. 659).

teaching of science as inquiry- transmitting concepts, principles, and facts . . . (and) conveying a realistic image of science and nature. (tell students about: how science is continually changing; problems posed and experiments performed; how data is converted into scientific knowledge) (Tamir, 1983 p. 659).

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Annotated Bibliography

Inquiry as a Goal for Learning Science

Hofstein, Avi, and Vincent N. Lunetta. "The Role of the Laboratory in Science Teaching: Neglected Aspects of Research." Review of Educational Research 52.2 (1982): 201-217.

From their survey of research of science laboratory studies the authors concluded that much of the research is yet inconclusive. While they reported that it is unreasonable to assert that the laboratory is effective for teaching all goals in science education, it does play an important part in the achievement of some of these goals. In studies that compared learning in the laboratory with conventional classroom structures, only nonsignificant results have been found, indicating that the laboratory is at least as effective as the conventional classroom in the measured areas. Sufficient data did exist to suggest that the laboratory was effective in promoting development of logic and some inquiry and problem-solving skills such as the understanding of scientific concepts and performing scientific process skills. Laboratories were also found to be effective in promoting positive attitudes toward science and in developing cooperation and communication.

Harpole, Sandra and Vernon Gifford. "Factors Contributing to Achievement in Statewide Physics Competition." Microfiche. ERIC ED 265 202 (1985): 1-10.

This article reported on a study done to determine what personal, cognitive, and school variables are predictors of high physics achievement. Students that scored high on the Mississippi State University Physics Competition Test were found to be typically males with high composite ACT scores and high ACT science scores. They had taken calculus, were from a school having several physics classes, and their high school laboratory experience consisted of experiments conducted in small groups. The implication for the teacher here was that students need small group laboratory experience as opposed to teacher demonstration or large group experiments to promote achievement in physics.

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Fuhrman, Marlene, Vincent N. Lunnetta and Shimshon Novick. "Do Secondary School Laboratory Texts Reflect the Goals of the 'New' Science Curricula?" Journal of Chemical Education 59.7 (1982): 563-565.

This article reported on the analysis of five chemistry laboratory books to determine if the goal of providing actual scientific inquiry, as advocated by many chemistry educators, had been met. The authors reported that in the materials examined, students are generally asked to follow a "cookbook" approach to experiments rather than design an experiment or carry out their own procedure. Students are seldom asked to hypothesize, explain, identify questions or design experiments. It is noted that this leaves a discrepancy between the stated goals for learning and the instructions found in laboratory handbooks. It is suggested that concerned teachers use supplementary materials to remedy this discrepancy. Data of the analysis is provided.

Staver, John R. and Mary Bay. "Analysis of the Project Synthesis Goal Cluster Orientation and Inquiry Emphasis of Elementary Science Textbooks." Journal of Research in Science Teaching 24.7 (1987): 629-643.

Eleven elementary science textbook series, which comprised approximately 90% of the national market, were analyzed for content. The results of the analysis of the activities/ experiments found in the textbooks revealed that 53% of the activities/experiments were confirmation experiences for concepts or relations already introduced in the text. None of the activities were open inquiry, 3% were guided inquiry, and the remaining 44% were structured inquiry. Furthermore, the portion of text space even allocated to activities was reported to be a small fraction of the total space in the chapters analyzed.

Tamir, Pinchas. "Inquiry and the Science Teacher." Science Education 67.5(1983): 657-672.

The author made the distinction between "teaching and learning by inquiry" and "teaching of science as inquiry". Data collected from a survey of experienced teachers and student teachers indicated that there is a great deal of confusion about the nature of inquiry. The results indicated that experienced teachers are more inclined to associate inquiry with scientific research, while the student teachers are more inclined to associate inquiry with learning and teaching.

Welch, Wayne, Leopold E. Klopfer, Glen S. Aikenhead, and James T. Robinson. "The Role of Inquiry in Science Education: Analysis and Recommendations." Science Education 65.1 (1981): 33-50.

Based on data collected by the authors, it was concluded that the desired state of science education whereby students learn about the processes and nature of scientific inquiry was not being achieved. They found that the desired degree of inquiry instruction to be rare. In light of failure of the present goal for teaching scientific inquiry, the authors proposed a new goal: "Every expected student outcome with respect to inquiry in science education should have psychological consistency, be compatible with personal goals, and have ecological consistency."

Teaching Scientific Inquiry

Renner, John W., Rosalie M. Grant, and Joan Sutherland. "Content and Concrete Thought." Science Education 62.2 (1978): 215-221.

The data from the research of 588 Oklahoma students, believed to be a typical sample, was given in this article which showed the percentages of concrete and formal learners by grade. The results were as follows:

Grade	Sample Size	% of Students Exhibiting: Concrete Thought	Formal Thought
7	96	83	17
8	108	77	23
9	94	82	18
10	94	73	27
11	99	71	29
12	97	66	34

Cantu, Luis and J. Dudley Herron. "Concrete and Formal Piagetian Stages and Science Concept Attainment." Journal of Research in Science Teaching 15.2 (1978): 135-143.

The differences in learning between concrete-operational students and formal-operational students was examined in this study. Since a substantial percentage of students at this level are not formal thinkers, their ability to learn abstract concepts is hindered. A method was devised using pseudoexamples to teach abstract concepts. While the concrete-operational group did show encouraging results using the pseudoexamples with abstract concepts, the gap between the two groups did not diminish as was hypothesized since the formal-operational group also responded well to the pseudoexamples and showed greater attainment as well. In all cases, teaching concrete or abstract concepts, the formal thinkers out performed the concrete thinkers.

Case, Robbie and Cathy Fry. "Evaluation of an Attempt to Teach Scientific Inquiry and Criticism in a Working Class High School." Journal of Research in Science Teaching 10.2 (1973): 135-142.

This article reported on a study that successfully taught low socioeconomic status 14-year-olds, who had not yet reached Piaget's stage of formal operations, to design controlled experiments. While the researchers did not claim to know the mechanism by which the learning took place, they did report that a large and statistically significant effect did take place. They concluded: 1) that the goal of teaching low SES 14-year-olds to evaluate and design experiments is not unrealistic and, 2) that predictions about classroom effects based on Piaget's normative developmental data should be made cautiously.

Kolodiy, George Oleh. "Cognitive Development and Science Teaching." Journal of Research in Science Teaching 14.1 (1977): 21-26.

Seventy subjects representing 3 distinct groups performed two tasks requiring formal reasoning to determine their cognitive level. The results were as follows:

	HIGH SCHOOL SOPHOMORES 2nd YEAR BIOLOGY	COLLEGE FRESHMAN SCIENCE MAJOR	COLLEGE SENIORS SCIENCE MAJOR
UPPER FORMAL	35%	32%	64%
LOWER FORMAL	50%	60%	28%
UPPER CONCRETE	15%	8%	8%

The results indicated that formal thinking is not a requirement for success in college level science since 8% were graduating with science degrees while still operating at the concrete level and another 28% were at the lower formal level.

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Daab, Marcia. "Improving Fifth Grade Students' Participation In and Attitudes Toward the Science Fair Through Guided Instruction." Microfiche. ERIC ED 297 968 (1988): 1-109.

This practicum report described the author's project designed to improve both the participation levels and attitudes of fifth grade students' science fair projects. A review of the literature supported the author's belief that 5th grade students may not have the process skills needed to do a research type project. In an attempt to remediate this void, the author designed a program which included teaching a 4 week mini-class to science fair students which included teaching a one hour science fair workshop for parents. While the quantitative data did not prove the project successful, the author reported there to be many positive qualitative results. Included in the paper is the workbook written by the author for the mini-class.

Bredderman, Theodore. "The Effects of Training on the Development of the Ability to Control Variables." Journal of Research in Science Teaching 10.3 (1973): 189-200.

This article reported on a study of training 5th and 6th graders to control variables. After a pre-test, two groups were provided training involving dependent and independent variables in 31 experiments. One training group received external reinforcement, the other training group was designed to induce internal cognitive conflict. The third group received no training, but took three tests: a pre-test, a post-test, and a retention test. During the course of the study, a significant number of students improved their test scores regardless of their group. The training groups demonstrated only slightly greater improvements than the control group, and there was no difference in improvement between the two experimental groups. It was concluded that the ability to control variables can be improved with numerous experiences with variables regardless of training which involves external reinforcement or the inducement of cognitive conflict or simply the repeated posing of the problem to be solved.

Tamir, Pinchas and Ruth Amir. "Inter-relationship Among Laboratoy Process Skills in Biology." Journal of Research in Science Teaching 24.2 (1987): 137-143.

The interrelationships among 21 process skills measured on an inquiry oriented practical biology test were analyzed using correlations and VARIMAX factor analysis. The associations and dissociations identified provided insight into the complex process of how process skills are learned. The fact that interrelationships existed pointed to the need to explicitly develop all related skills. It cannot be assumed that the necessary prior knowledge exists.

Yeany, Russell H., Kueh Chin Yap, and Michael J. Padilla. "Analyzing Hierarchical Relationships Among Modes of Cognitive Reasoning and Integrated Science Process Skills." Journal of Research in Science Teaching 23.4 (1986): 277-291.

A hierarchical relationship, both linear and branching, was established among 11 formal reasoning abilities and integrated science process skills as determined from the computer analysis of two data collection instruments administered to students in grades 7-12. As could be expected, the resulting hierarchy showed the Piagetian modes of reasoning entangled with the process skills. The message was that the teaching of the process skills must be ordered in the manner suggested by the hierarchy. Care must be taken that the prerequisite skills are intact before attempting to move up the hierarchy.

Novak, Joseph D., D. Bob Gowin, and Gerald T. Johansen. "The Use of Concept Mapping and Knowledge Vee Mapping with Junior High School Science Students." Science Education 67.5 (1983): 625-645.

A preliminary study of 7th and 8th graders' ability to use concept mapping and Vee mapping strategies indicated that this task was possible, with the 7th graders having scored higher than 8th graders. Both success and failure was found in high and low ability students as indicated by standardized achievement tests. This indicated that concept mapping and Vee mapping requires different abilities and/or motivation than is measured by standardized tests or typical classroom exams.

Novak, Joseph D. "An Alternative to Piagetian Psychology for Science and Mathematics Education." Science Education 61.4 (1977): 453-477.

The author cited evidence, work done by members of his research group, that supported Ausubel's theory of cognitive learning. Most of the work was done with a series of audiotutorial science lessons developed for first- through third-grade children. The conclusion was that a significant percentage of young children did acquire and use highly formal concepts to explain scientific phenomena, with explanations at a level normally reserved for an adult, after specially designed concept-oriented instruction.

Arzi, Hanna J., Ruth Ben-Zvi, and Uri Ganiel. "Proactive and Retroactive Facilitation of Long-term Retention by Curriculum Continuity." American Educational Research Journal 22.3 (1985): 369-388.

This article presented research that supported a science curriculum composed of a hierarchical sequence of learning as opposed to a discontinuous array of discrete courses. The results were based on a three year study of students beginning in physical science at grade 7. One group continued to study related physical science in grade 8, while the other group did not. Two effects were noted: 1) prior knowledge from grade 7 material over a 2-year period was higher in the group that had studied physical science in grade 8. This research supported Ausubel's theory.

Wahl, Maureen and Frank Besag. "Gender Attributions and Math Performance." Microfiche. ERIC ED 276 620 (1986): 1-3.

This study looked at various explanations (ability, effort, environment, and task) students make for their performance in algebra. Significant to this study was the finding that students who participated in competitive activities tended to attribute their success and failure to their own effort. The implication of this finding is that competition teaches students to rely on their own effort and to attribute their success and failure to their innate ability or inability. The authors concluded that competitors are more likely to be able to be encouraged to improve their performance by increasing their effort than noncompetitors

Humphreys, Barbara, Roger T. Johnson, and David W. Johnson. "Effects of Cooperative, Competitive and Individualistic Learning on Students' Achievement in Science Class." Journal of Research in Science Teaching 19.5 (1982): 351-356.

This article reports on a research study designed to determine which method of instruction was most effective for teaching science to middle ability junior high students: cooperative, competitive or individualistic. The conclusion was that for junior high science students, the cooperative method was the most effective. The students in the cooperative group scored higher on both short-term unit tests and long-term retention tests, had fewer absences, and on attitude scales, reported their condition more positively than did the students in the competitive and individualistic conditions. This study clearly had implications for cooperative teaching methods for junior high science.

Johnson, David J. and Roger T. Johnson. "Instructional Goal Structure: Cooperative, Competitive, or Individualistic." Review of Educational Research 44.2 (1974): 213-240.

This article presented an extensive review of the literature dealing with three types of instructional goal structures: cooperative, competitive and individualistic. The conclusion was that the cooperative goal structure should be used for almost all instructional activities including problem solving, group productivity, creating positive attitudes toward instructional activities and increasing divergent and risk-taking thinking. The competitive goal structure should almost never be used. Research on the individualistic goal structure was reported to be inadequate. The authors concluded that competition should only be used in simple activities that require little help from another person; in situations where winning or losing does not produce a great deal of anxiety; and with clearly specified goals.

Tjosvold, Dean and Paul M. Maring. "The Effects of Cooperation and Competition on Student Reactions to Inquiry and Didactic Science Teaching." Journal of Research in Science Teaching 14.4 (1977): 281-288.

The effects of cooperative vs competitive student interaction were compared in inquiry teaching and didactic teaching methods. It was found that cooperative student interaction was preferred by students in all instances. While the inquiry teaching method was much more accepted in the cooperative condition, the cooperative or competitive conditions did not greatly affect student acceptance of the didactic teaching method. Part of the frustration related with inquiry learning was observed to be the students' need to get the "right" answer. This may be eased with cooperative learning. The need for clear competitive goals was emphasized. Students were found to be more accepting of competition in the didactic rather than the inquiry teaching method.

Okebukola, Peter and Meshach B. Ogunniyi. "Cooperative, Competitive, and Individualistic Interaction Patterns Effects on Students' Achievement and Acquisition of Practical Skills." Journal of Research in Science Teaching 21 (1984): 875-884.

This article reports on a study done to determine the effect of cooperative, competitive and individualistic science laboratory styles on students' cognitive achievement and acquisition of practical skills. Homogeneous groups of high, middle and low achievers and heterogeneous groups were tested. The best results for obtaining cognitive achievement was seen by the cooperative groups. Surprisingly, in the area of practical skills, the competitive group outperformed the cooperative and individualistic groups. While the homogeneous high group performed the best, the low achievers made more gains in the heterogeneous group.

Okebukola, Peter Akinsola. "Cooperative and Competitive Interaction Techniques In Strengthening Students' Performance in Science Classes." Science Education 69.4 (1985): 501-509.

This article reports the findings of a study done to investigate the effects of cooperative and competitive interaction techniques on student performance in science. The study was based on three models: 1) "pure" cooperation, 2) cooperation-competition and 3) "pure" competition. The results indicated that the cooperative-competitive method is the most effective method of the three for student performance in science. The implication of the study for the classroom teacher is cooperative teams working together to master material followed by challenging other teams in competition. The author believes that the natuie of science classes are unique, making "pure" cooperative leaning less effective in science classes than reported in other research.

Motivational Structures

Slavin, Robert E. "Students Motivating Students to Excel: Cooperative Incentives, Cooperative Tasks, and Student Achievement." The Elementary School Journal 85.1: 35-63.

A review of 46 field experiments on cooperative learning showed strong evidence that student achievement can be enhanced by use of group rewards for individual learning. This held true whether students were allowed to study together as a group or not. The students who could study in groups but received no group rewards learned less that all other students including those who studied individually and received individual rewards. Students working together for a team reward, helped each other substantially more than when they could work together but received no group reward. The cooperative learning method using group rewards for individual learning may have been the most successful because of its ability to change peer norms to favor academic efforts--group members try to make the group successful by encouraging each other to excel.

Michaels, James. "Classroom Reward Structures and Academic Performance." Review of Educational Research 47.1 (1977): 87-98.

This article reviews the literature of ten research studies that compared the effect of four different reward structures to academic performance. The reward structures studied were: 1) individual reward contingencies, 2) group reward contingencies, 3) individual competition, and 4) group competition. The review consistently showed individual competition to be the most effective reward structure in strengthening independent academic performance. Caution was sighted in over generalizing these findings because individual competition will work very well for high ability students who will receive rewards and not at all for low ability students who will never receive rewards.

Angier, Natalie. "The Westinghouse Kids." Discover 2.5 (1981): 40-43.

This article reported on the annual Westinghouse Science Talent Search, the most sophisticated high school science contest in the United States. The WSTS has been awarding the nation's top science students since 1941. Each year the 300 seniors, out of nearly 1,000 who submit the most outstanding independent research reports are named to the Talent Search Honors group. From this group, forty are designated as Trip Winners, and are invited to Washington D.C. for further competition and a chance to win college scholarships which range from $12,000 for first prize, to $5,000 for the tenth, to $500 for each of the remaining 30 finalists. Most of the finalists in the past ten years were in the top 5 percent of U.S. high school students.

Tainman, J. Jaap, Roger Farr and B. Elgit Blanton. "Increase in Test Scores as a Function of Material Rewards." Journal of Educational Measurement 9.3 (1972): 215-223.

This article reported on a study which showed that offering material rewards immediately prior to testing did indeed increase test scores. Two groups with comparable pre-test scores on a reading achievement test were provided with the same instruction for a period of four weeks, at which time they were retested. The control group was simply told that they had to take the test over again in order to find out how much they had learned since the first test. The other group was offered radios, sweaters and pencils for increasing their own scores. The group offered material rewards out performed the control group by three months. The experimental group was seen to be more motivated by attempting more items and having a higher number correct than the control group.

Maheady, Larry, Diane M. Sainato, and George Maitland. "Motivated Assessment: The Effects of Extrinsic Rewards on the Individually-Administered Reading Test Performance of Low, Average, and High IQ Students." Education and Treatment of Children 6.1 (1983): 37-46.

This article reported the findings of a study designed to investigate the effects of extrinsic rewards on individually administered reading test performance across IQ levels. The findings of this investigation were that all students, regardless of the IQ levels, improved their reading test performance under extrinsic reward conditions significantly more than no reward or feedback reward conditions. Similar studies found extrinsic rewards only effective with low IQ students. It was noted that rewards must be chosen that are reinforcing for the participants. This study was limited to performance on standardized reading tests, therefore should be generalized with caution.

Bebeau, M.J. and H.J. Sullivan. "Educational Technology Research: Learning Incentives Preferred by University Students." Educational Technology 22.8 (1982): 32-35.

This article reported on a study done to determine which performance-contingent incentives commonly under the control of the teacher were most preferred by students. Students were asked to select preferred incentives on two different rating scales. Results of both scales were similar with 'release from the final exam', 'positive comments from the instructor' and 'points toward the course grade' consistently being chosen as the most positive. 'Assisting the instructor' and 'no reward at all' were chosen to be the least favorite incentives. The other incentives with medium preference were: 'field trips', 'release from class attendance', 'letter grade indicating quality', and 'recognition in publication'. It was not proclaimed that this ranking would be valid for all groups and was suggested that incentives be individualized to each student where possible.

Deci, Edward J. "Effects on Externally Mediated Rewards on Intrinsic Motivation." Journal of Personality and Social Psychology 18.1 (1971): 105-115.

The effects of external rewards on intrinsic motivation was the topic of this article. A review of the research done prior to this study inconclusively stated that external rewards decrease intrinsic motivation. Two laboratory experiments and one field experiment were conducted. Money was used as the reward in two experiments and verbal praise was used in a third experiment. The conclusion made was that money does seem to negatively affect one's intrinsic motivation for an activity, whereas rewards such as social approval do not affect one's intrinsic motivation. It was believed by the experimenter that money, as used in our culture, is perceived to "buy off" one's internal control. The author goes on to "explain" previous experiments in light of his findings.

Schunk, Dale H. "Enhancing Self-Efficacy and Achievement Through Rewards and Goals: Motivational and Informational Effects." Journal of Educational Research 78.1 (1984): 29-34.

This article reported on a study that showed that students provided with both goals and rewards leads to both higher initial expectations for goal attainment and [illegible]her performance than either the rewards-only or goals-only [illegible]. The rewards only group was seen to have more go[illegible]ent and judged themselves more certain of attaining [illegible] goals than the goals-only subjects. Goals were seen as important for providing a clear standard against which to assess progress, otherwise students may not be aware of how well they are performing. Rewards should be clearly linked to goal attainment. In the absence of rewards, teachers need to provide explicit information indicating that goals are attainable, especially when the goals are perceived as difficult.

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Rosswork, Sandra. "Goal Setting: The Effects on an Academic Task With Varying Magnitudes of Incentives." Journal of Educational Psychology 69.6 (1977): 710-715.

The results of an experiment designed to measure the effects of goals and monetary incentives on performance was reported in this article. The results indicated that specific difficut goals lead to higher performance than nonspecific goals ("do your best") across four incentive levels. The specific difficult group maintained significantly higher performance levels than the nonspecific group after the withdrawal of reinforcement. Specific difficult goals produced higher performance levels regardless of whether incentives were offered and regardless of the amount of incentives.

Working Outside of the Classroom

Keith, T. Z. "Time Spent on Homework in High School Grades." Journal of Educational Psychology 74.2 (1982): 248-253.

The analysis of the homework habits of more than 20,000 students revealed that time spent on homework did indeed have a direct effect on achievement. The only factor observed to have more effect on achievement than time spent on homework was intellectual ability. It was found that by spending only one to three hours per week on homework, that the average low-ability student can achieve grades equivalent to verage high-ability student who does not do homework. It wa also found that current homework demand was rather low.

Tamir, Pinchas. "Homework and Science Learning in Secondary Schools." Science Education 69.5 (1985): 605-618.

In a survey of 215 students which asked various questions regarding science homework, it was found that nearly all students had a quiet place to do homework; most of their parents supported homework, although very few parents ever checked student homework; nearly half of the students saw a value of homework; and observations/experiments were seldom used as homework. Students who regularly do all their science homework were found to value their science homework and tend to be high achievers.

Olson, Linda Sue. "The North Dakota Science and Engineering Fair--Its History and a Survey of Participants." Microfiche. ERIC ED 271 325 (1985): 1-126.

The compilation of a survey of the North Dakota State Science and Engineering Fair finalists from 1951-1985 was reported in this manuscript. Part of the survey examined the issue of whether science fair participation is best as a voluntary activity or rather as a required activity. Seventy-six percent of the group reported that they participated as volunteers. As volunteers, the students were more self-motivated, with 100% of this group having reported that they received no outside help from instructors or parents. The non-volunteers required both more encouragement and help from instructors or parents. Both groups reported similar benefits: travel, poise with evaluators, and the challenge of a professional's evaluation, with the required group even having reported benefits more favorably than the volunteers.

Wiygul, Sherrill and Vernon Gifford. "The Effect of the Use of Outside Facilities and Resources on Success in Secondary School Science Fairs." Microfiche. ERIC ED 288 740 (1987): 1-10.

The paper reported on a study of participants of the 1987 Mississippi Region V Science Fair to determine the effect of outside help in completing a winning science fair project. The outside facilities used by those students placing first, second, or third (winners) were compared to the outside facilities used by those students who did not place or receive an honorable mention (non-winners). Eight factors were determined to be significant in differentiating the winners from the non-winners. The non-winners were found to have spent more hours using parents' or friends' businesses; using parents' or friends' shops; and obtaining help from a secondary school teacher than did the winners. The best predictors for the winners were the use of college or university resources and the direct cost of completing the project. Other predictors for the winners were: larger number of hours spent using high school labs or other resource facilities and the use of the public library. It was concluded that the location of a student's secondary school may determine his potential to win. Students not having access to college or university facilities inevitably rely more on parents, friends and teachers.

Roe, Frank W. and Valerie K. Roe. "Westinghouse Science Talent Search in Illinois Secondary Schools from 1970-84." Illinois School Research and Development 22.1 (1985): 18-26.

The demographics of the participants of the Westinghouse Science Talent Search, particularly the Illinois participants were examined in this article. The WSTS reports normally require supplementary information most frequently found only in university libraries or science departments involved in state-of-the-art research. Obviously, these types of facilities are not obligatory since none of Illinois 1970-1984 winners were from the areas of or appeared to have used the facilities of any of Illinois major universities nor are any of the students from anywhere near the high technology corridor between Chicago's western suburbs and Aurora.

Summary

Inquiry as a Goal for Learning Science

Since the launching of the SPUDNIK in 1957, Americans have been concerned with the quality of science education which has resulted in curriculum reforms (Novak, 1977). Inquiry learning has been advocated by many as a central goal of science learning (Tamir, 1983; Welch et al.).

In a review of recent research literature in the area of science laboratory instruction, it was concluded that there was insufficient data to confirm or reject the effectiveness of the laboratory as a teaching method. In studies that compared learning in the laboratory with conventional classroom structures, only nonsignificant results have been found. This indicated that the laboratory and conventional classroom structures were equally effective in the measured areas. On the other hand, sufficient data did exist to suggest that the laboratory was effective in promoting development of logic and some inquiry and problem-solving skills such as the understanding of scientific concepts and performing scientific process skills. Laboratories were also found to be effective in promoting positive attitudes toward science and in developing cooperation and communication (Hofstein and Lunetta).

Benefits from student involvement in science laboratories were seen in a study of the high scorers on the Mississippi State University Physics Competition Test. The study revealed potential school variables as predictors for high physics achievement. The high scorers tended to have taken calculus, were from a school having several physics classes, and their high school laboratory experience consisted of experiments conducted in small groups as opposed to teacher demonstration or larger groups (Harpole and Gifford).

In spite of the stated goals favoring scientific inquiry, much of what is found in the textbooks is not inquiry. An analysis of five chemistry laboratory books revealed that students are generally asked to follow a "cookbook" approach to experiments rather than design an experiment or carry out their own procedure. Students are seldom asked to hypothesize, explain, identify questions or design experiments (Fuhrman, Lunetta, and Novick). An analysis of the activity/ experiment content of eleven elementary science textbook series, which comprised approximately 90% of the national market, revealed that 53% of the activities/experiments were confirmation experiences for concepts or relations already introduced in the text. None of the activities were open inquiry, 3% were guided inquiry and the remaining 44% were structured inquiry. Furthermore, the proportion of text space even allocated to activities was reported to be a small fraction of the total space in the chapters analyzed (Starver and Bay).

The lack of inquiry may in part be attributed to confusion over its meaning. Tamir has made a distinction between "teaching and learning by inquiry" and "teaching of science by inquiry". Data collected from a survey of experienced teachers and student teachers revealed that experienced teachers were more inclined to associate inquiry with scientific research, while the student teachers were more inclined to associate inquiry with learning and teaching (Tamir, 1983).

It was suggested by one science educator that a new pattern of science teaching was needed in the classroom. This was based on data collected that showed that teaching science by inquiry simply was not being done. It was hypothesized that the goal of teaching inquiry skills to all students may not be realistic since some students may not have the psychological capacity, personal desire or be in an environment conducive to learning by inquiry. Since the observed state of inquiry education was determined to be a failure, the following new goal was proposed:

> "Every expected student outcome with respect to inquiry in science education should have psychological consistency,be compatible with personal goals, and have ecological consistency." (Welch, et al.)

Teaching Scientific Inquiry

It has come into question whether school age children are even capable of learning scientific inquiry. Many researchers look to Piaget's stages of cognitive development for guidance.

According to the theories of Piaget, the development of formal structures by adolescents is the most important event in the thinking found in this period. In describing the development of adolescent thinking, Inhelder and Piaget stated the following:

> "The subjects' reactions to a wide range of experimental situation demonstrate that after a phase of development (11-12 to 13-14 years) the preadolescent comes to handle certain formal operations (implication, exclusion, etc.) successfully, but he is not able to set up an exhaustive method of proof. But the 14-15-year-old adolescent does succeed in setting up proof (moreover,spontaneously, for it is in this area that academic verbalism is least evident). He systematically uses methods of control which require the combinatorial system-i.e., he varies a single factor at a time and excludes the others ("all other things being equal"), etc. But, as we have often seen, this structuring of the tools of experimental verification is a direct consequence of the development of formal thought and propositional logic."(Inhelder and Piaget p. 347)

But Piaget's premise of 14-15-year-old adolescents being capable of formal thought has been questioned. The data from the research of 588 Oklahoma students, believed to be a typical sample, is given as follows:

Grade	Sample Size	% of Students Exhibiting: Concrete Thought	Formal Thought
7	96	83	17
8	108	77	23
9	94	82	18
10	94	73	27
11	99	71	29
12	97	66	34

From the data we can observe that the percentage of students in formal thought is relatively low throughout the junior/ senior high school years (Renner, et al.).

Since many science concepts presented at the high school and college level are abstract, thus requiring formal-operational thought, a method was devised using "pseudoexamples" to teach abstract concepts to the many concrete-operational thinkers. It was hypothesized that the learning gap between concrete- and formal-operational groups would diminish. While the concrete-operational group did show encouraging results, the gap between the two groups did not diminish since the formal-operational group also responded well to the pseudoexamples and showed greater attainment as well. In all cases, teaching concrete or abstract concepts, the formal thinkers out performed the concrete thinkers (Cantu and Herron).

Another study reported success in teaching low socioeconomic status 14-year-olds, who had not yet reached the stage of formal operations, to design controlled experiments and to criticize poorly controlled experiments. While the researchers did not claim to know the mechanism by which the learning took place, they did report that a large and statistically significant effect did take place. They concluded: 1) that the goal of teaching low socioeconomic status 14-year-olds to evaluate and design experiments is not unrealistic and, 2) that predictions about classroom effects based on Piaget's normative developmental data should be made cautiously (Case and Fry).

And yet another study questions the importance of Piaget's theory. In this study, the cognitive levels of seventy subjects, of three distinct groups, as determined by their individual performance on two tasks requiring formal reasoning were determined to be as follows:

	HIGH SCHOOL SOPHOMORES 2nd YEAR BIOLOGY	COLLEGE FRESHMAN SCIENCE MAJOR	COLLEGE SENIORS SCIENCE MAJOR
UPPER FORMAL	35%	32%	64%
LOWER FORMAL	50%	60%	28%
UPPER CONCRETE	15%	8%	8%

The results indicated that formal thinking is not a requirement for success in college level science since 8 % of the college seniors were still at the concrete level and another 28% were at the lower formal level. The assumption was that if the development of formal thought was indeed a criteria for advanced scientific thought, then non-formal thinkers would not be found in college senior science courses (Kolodily).

It cannot be concluded, however, that teaching science process skills is a simple task, nor is it always successful. In a practicum report which described a project to improve both the participation levels and attitudes of fifth grade students' science fair projects, the author reported that the quantitative data did not prove the project to be a success. This was in spite of the author's development of a 4-week mini-class with a specially created workbook and a one hour workshop for parents, all designed for the expressed purpose of remediating the students' known void of science process skills. In spite of the well intended remediation process, neither participation nor attitude showed any increase over previous years' data (Daab).

In another study of 5th and 6th grade students, the ability to control variables indicated that training is not the determinent factor as much as merely repeated posing of the problem to be solved. Three groups took three tests: a pre-test, a post-test, and a retention test. Two groups received training with either external reinforcement or internal cognitive conflict. During the course of the study, students in all three groups improved their scores. The training groups demonstrated only slightly better results than the control group. It was concluded that the ability to control variables can be improved by numerous experiences with variables (Bredderman).

The complexity of learning science process skills is only beginning to be understood. The interrelationships of 21 process skills were analyzed using correlations and

and computer analysis. The associations and dissociations identified provided insight into the complex process of how process skills are learned. The fact that interrelationships were shown to exist, emphasized the need to explicitly develop all related skills. It cannot be assumed that necessary prior knowledge exists without risking the achievement of all other interrelated process skills (Tamir, 1987).

The relationships between process skills were demonstrated in a similar way in another computer analysis which mapped the hierarchical relationship, both linear and branching, among eleven formal reasoning abilities and science process skills. As could be expected, the hierarchy showed the Piagetian modes of reasoning entangled with the process skills. This hierarchical structure reiterates Tamir's conclusion that it is essential for all prerequisite knowledge to be intact for successful learning to take place (Yeany, et al.).

The notion that learning takes on a hierarchical relationship is also supported by Ausubel and his followers, who have come to believe that Piaget's theory has developed too many exceptions to be useful (Novak, 1977). While Ausubel's theory is not conclusive and needs refinement, it does provide the science educator a viable alternative to base his strategies.

The principles of Ausubel's theory have experienced success in field studies. A preliminary study of 7th and 8th graders ability to use concept mapping and Vee mapping strategies, types of advanced organizers, indicated that this task was possible. In fact, the 7th graders scored higher than 8th graders. Both success and failure was found in high and low ability students. This indicated that concept mapping and Vee mapping required different abilities and/or motivation than is typically found in the classroom (Novak, Gowan, and Johansen).

Support for Ausubel's theory was cited once again by Novak, in a field study done by members of Novak's research group. A specially designed series of concept-oriented audio-tutorial science lessons were developed for first- through third-grade students. It was concluded that a significant percentage of young children had acquired and used highly formal concepts to explain scientific phenomena, with explanations at a level normally reserved for an adult (Novak,1977).

Teaching science curriculum in a hierarchical sequence presents yet another benefit when the three year study of 7th graders scheduled into a hierarchical sequence of learning as opposed to a discontinuous array of discrete courses is considered. Two groups of 7th graders were observed. Both groups studied physical science in 7th grade. One group continued to study physical science in the 8th grade, while the other did not. Two effects were noted: 1) prior knowledge from grade 7 facilitated learning in grade 8 and, 2) retention of grade 7 material over a 2-year period was higher in the group that continued to study physical science in grade 8 (Arzi, et al.).

Instructional Goal Structures

The research on instructional goal structures as applied to science and therefore more specifically to science fairs, in most instances compares the effects of cooperative, competitive, and individualistic learning. Studies are not prevalent that examine competitive verses concompetitive nor individual effort verses team effort. An examination of the effects of cooperative, competitive, and individualistic structures on learning follows.

A benefit of competition was observed in a study of math performance. It was found that students who participated in competitive activities tended to attribute their success and failure to their own effort. The significance of this is that if students assume responsibility for their own success or failure, rather than attribute it to their innate ability or inability, then they are more likely to be able to be encouraged to improve their performance by increasing their effort (Wahl).

A study of middle ability junior high science students demonstrated their preference for the cooperative method of learning when compared with competitive or individualist learning methods. The students in the cooperative group scored higher on both short-term unit tests and long-term retention tests, had fewer absences, and on attitude scales, reported their condition more positively than did the students in the competitive or individualistic conditions. In this study, the cooperative structure was clearly the most effective (Humphreys, et al.).

An extensive review of the literature dealing with the above mentioned goal structures, cooperative, competitive, and individualistic, again favored the cooperative goal structure. Evidence was cited that concluded that the cooperative goal structure should be used for almost all instructional activities including problem solving, group productivity, creating positive attitudes toward instructional activities and increasing divergent and risk-taking thinking. It was reported that research on the individualistic goal structure was inadequate and that the competitive goal structure should almost never be used. The authors concluded that the only time that competition is an appropriate learning structure is in simple activities that require little help from another person; in situations where winning or losing does not produce a great deal of anxiety; and with clearly stated goals (Johnson and Johnson).

When the effects of cooperative and competitive structures are applied to inquiry or didactic science teaching methods, again the cooperative structure was preferred by students in both the inquiry and didactic teaching methods. An interesting finding was that little difference existed in the students acceptance of the didactic approach be it in the cooperative or competitive structure. The inquiry approach on the other hand, was much more accepted when presented in the cooperative structure. Students were more accepting of the competitive structure in the didactic approach than the inquiry approach. This points to the need for clear goals when the competitive structure is used. Part of the frustration related with inquiry learning was observed to be the student's need to get the "right" answer. This may be eased with cooperative learning (Tjosvold and Marino).

In yet another study comparing the effects of cooperative, competitive and individualistic structures effects on the learning of science, the variables of cognitive achievement and acquisition of practical skills in the science laboratory were added. Once again, the cooperative structure was determined to be the best for obtaining cognitive achievement. Somewhat surprisingly though, the competitive structure proved to be the most effective in the area of practical skill attainment. As would be expected, the homogeneous high group performed the best, while the low achievers made more gains in the heterogeneous group (Okebukola and Ogunniyi).

A subsequent study done by Okebukola examined the effects on student performance in science by three different models: 1) "pure" competition, 2) cooperation-competition and, 3) "pure" competition. The results indicated that the cooperative-competitive method is the most effective method of the three for student performance in science. This could be implemented by having cooperative teams work together to master material followed by challenging other teams in competition (Okebukola).

Motivational Structures

Motivating students to work up to their potential is a primary concern for all teachers. Research on motivation is available. An extension of the goal structure studies can be observed by looking at the studies that added the effects of rewards to the cooperative, competitive, and individualistic goal structures studies. Two such studies have been summarized below, followed by research on rewards and goals.

A review of 46 field experiments on cooperative learning revealed strong evidence that student achievement can be enhanced by the use of group rewards for individual learning. This held true whether students were allowed to study together as a group or not. The students who could study in groups, but received no group rewards, learned less than all other students, including those who studied individually and received individual rewards. Students working together for a team reward helped each other substantially more than when they could work together, but received no group reward. The cooperative learning method using group rewards for individual learning may have been the most successful because of its ability to change peer norms to favor academic efforts--group members try to make the gro·· successful by encouraging each other to excel (Slavin).

In another research review, the effects of competition and reward contingencies on student performance in individual and group structures was examined. Ten research studies that were categorized into to one of four categories were analyzed. The categories were: 1) individual reward contingencies, 2) group reward contingencies, 3) individual competition and, 4) group competition. The review consistently showed individual competition to be the most effective reward structure in strengthening independent academic performance. Caution was sighted in over generalizing these findings because individual competition will work very well for high ability students who will receive rewards and not at all for low ability students who will never receive rewards (Michaels).

Evidence of rewards working well to motivate high ability students, while having no effect on low ability students, has been seen in the annual Westinghouse Science Talent Search, the most sophisticated high school science contest in the United States. The contest, which has been opened to U.S. high school seniors, has not had many entries--usually just under 1,000. Those that have entered have had a fair chance of recognition. The 300 students who submitted the most outstanding independent research reports were named to the Talent Honors group. From this group, forty were designated as Trip Winners, and were invited to Washington D.C. for further competition and a chance to win college scholarships which ranged from $12,000 for first prize, to $5,000 for the tenth, to $500 for each of the remaining 30 finalists. Most of the finalists from the 1970's were in the top five percent of U.S, high school students, thus the high rewards were effective for only the most able (Angier).

The effect of extrinsic rewards on student performance on reading achievement tests has had favorable results. Two studies used similar set-ups: similar groups with comparable pre-test scores on a reading achievement tests were provided with the same instruction and then retested. Immediately prior to the post-test, rewards were offered to the experimental groups. In one study, students in the experimental group were offered radios, sweaters and pencils contingent upon increasing their own score. The group offered material rewards out performed the control group by three months. The experimental group was seen to be more motivated by attempting more items and having a higher number correct than the control group (Tainmain, et al.). In a similar study, the effect of extrinsic reward, feedback reward, and no reward conditions on reading achievement across IQ levels were examined. It was found, that regardless of IQ level, students improved their reading scores significantly more under the extrinsic reward conditions than no reward or feedback reward conditions. It was noted that previous studies found that extrinsic rewards were only effective with low IQ students. It may have been that the rewards chosen by the investigators were not reinforcing for the participants (Maheady, et al.).

Care in selecting rewards that are reinforcing to students was illustrated in another study. A list of performance-contingent incentives commonly under the control of the teacher were ranked by college students. The results showed that some rewards commonly used by teachers only had medium or low preference for students (Bebeau and Sullivan).

While extrinsic rewards have been shown to improve performance, there has been concern that extrinsic rewards will decrease intrinsic motivation. A study involving two laboratory experiments and one field study investigated this issue. Money was used as the reward in two experiments and verbal praise was used in a third experiment. The conclusion was that money does seem to negatively affect one's intrinsic motivation for an activity, whereas rewards such as social approval do not affect one's intrinsic motivation. It was believed by the experimenter that money as used in our culture is perceived to "buy off" one's internal control (Deci).

Goals were shown to be important in a student's acceptance of competition and appear to also be important motivators. One study showed that students provided with both goals and rewards leads to both higher initial expectations for goal attainment and higher performance than either the rewards-only group or goals-only groups. The rewards + goals group was seen to have more goal commitment and judged themselves more certain of attaining their goals than the goals-only subjects. Goals were seen as important for providing a clear standard against which to assess progress, otherwise students may not be aware of how well they are performing. Rewards should be clearly linked to goal attainment. In the absence of rewards, teachers need to provide explicit information indicating that goals are attainable, especially when the goals are perceived as difficult (Schunk).

If given a choice of goals or money to influence performance, it appears that goals are more effective. In an experiment designed to measure the effects of goals and monetary incentives on performance, it was concluded that specific difficult goals lead to higher performance than nonspecific goals ("do your best") across four incentive levels. The specific difficult group maintained significantly higher performance levels than the nonspecific group after the withdrawal of reinforcement. Specific difficult goals produced higher performance levels regardless of whether incentives were offered and regardless of the amount of incentives (Rosswork).

Working Outside of the Classroom

Before concluding, the need for activity outside of the classroom structure has been examined. The areas of homework, resource persons, and facilities have been considered.

The analysis of the homework habits of more than 20,000 students revealed that time spent on homework did indeed have a direct effect on achievement. The only factor observed to have more effect on achievement than time spent on homework was intellectual ability. It was found that by spending only one to three hours per week on homework, that the average low-ability student can achieve grades equivalent to a average high-ability student who does not do homework. It was also found that current homework demand was rather low (Keith).

In another survey of 215 students which asked various questions regarding science homework, it was found that nearly all students had a quiet place to do homework; most of their parents supported homework, although very few parents ever checked student homework; nearly half of the students saw a value of homework; a little over half preferred to have homework; and observations/experiments were seldom used as homework. Students who regularly did all their science homework were found to value their science homework and tended to be high achievers (Tamir, 1985).

Among the finalists of the North Dakota Science and Engineering Fair, it was found that encouragement and help from parents and teachers was needed more often for students

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required to do a science fair project than those students who participated as volunteers. The volunteer group was seen to be more self-motivated, with 100% of the group having reported that they received no outside help on their projects from instructors or parents (Olson).

The need for parent and/or teacher involvement was questioned in a study of participants of the 1987 Mississippi Region V Science Fair. The outside facilities used by those students placing first, second, or third (winners) were compared to the outside facilities used by those students who did not place or receive an honorable mention (non-winners). Eight factors were determined to be significant in differentiating the winners from the non-winners. The non-winners were found to have spent more hours using parents' or friends' businesses; using parents' or friends' shops; and obtaining help from a secondary school teacher than did the winners. The best predictors for the winners were the use of college or university resources and the direct cost of completing the project. Other predictors for the winners were: larger number of hours spent using high school labs or other resource facilities and the use of the public library. It was concluded that the location of a student's secondary school may determine his potential to win. Students not having access to college or university facilities inevitably rely more on parents, friends and teachers (Wiygul and Gifford).

A study of the demographics of the Illinois Westinghouse Science Talent Search winners from 1970-1984 did not find that the student's location near a major university to be a determining factor for identifying winners. While it was acknowledged that the research reports required for such an endeavor were generally assumed to require supplementary information most frequently found only in university libraries or science departments, the facts did not find this relationship. None of the Illinois winners from 1970-1984 were from the areas of or appeared to have used the facilities of any of Illinois' major universities nor were any of the students from anywhere near the high technology corridor between Chicago's western suburbs and Aurora (Roe and Roe).

Conclusion

Inquiry as a Goal for Learning Science

It seems that inquiry as a goal for learning science is a worthy goal. Even if measured learning in the laboratory is only equally as effective as learning in the conventional classroom, the laboratory is an effective learning structure that is credited with promoting positive attitudes towards science and developing cooperation and communication as well (Hofstein and Lunetta). The reported lack of inquiry in the classroom (Welch, et al.), may be due to confusion on the teacher's part (Tamir,1983), and/or lack of inquiry materials in textbooks (Fuhrman, Lunetta, and Novicki; and Starver and Bay).

Teaching Scientific Inquiry

Research indicates that large percentages of school age children are not formal thinkers (Renner, et al.; and Kolodily), but even so it does not make the teaching of science by inquiry to non-formal thinkers impossible (Cantu and Herron; Case and Fry; Kolodily; and Bredderman). It was shown that learning the process skills is a complex process due to interrelationships between the skills (Tamir, 1987; and Yeany,et al.). There is some support for the use of Ausubel's Theory as a model for science learning (Novak, Gowan, and Johansen; Novak, 1977; and Arzi, et al.).

Instructional Goal Structures

Clearly the cooperative structure is the prefered instructional structure for most learning situations (Wahl; Humphreys, et al.; Johnson and Johnson; and Tjosvold and Marino), certainly for cognitive achievement (ibid.; and Okebukola and Ogunniyi). There is some indication that the competitive structure may be effective in some instances (Wahl; Johnson and Johnson; and Okebukola). Should the competitive structure be used, it is important to provide clearly stated goals (Johnson and Johnson; and Tjosvoid). The team approach, using the cooperative-competitive structure was found to be the most effective structure for science learning (Okebukola).

Motivational Structures

Without a doubt, clearly stated goals should be given in all learning situations to promote motivation (Schunk; and Rosswork). Extrinsic rewards have been shown to be effective in improving student performance (Slavin; Tainmain; and Maheady), especially when paired with goals (Schunk). Care should be taken to choose rewards that are perceived to be desirable (Maheady; and Bebeau); and money should not be used as a reward (Deci; and Rosswork). Rewards are effective across all IQ levels (Maheady) and while rewards are very effective in the individual competition structure, this is true only for the high ability students who have a chance of receiving a reward (Michaels). The best all round reward structure was determined to be the cooperative structure where group rewards are given for individual effort (Slavin).

Working Outside the Classroom

It can be concluded that homework improves student achievement (Keith; and Tamir). While it was reported that most parents supported homework, although very few ever checked homework (Tamir, 1985), it does not seem to matter since most of the "winners" reported receiving little or no help from parents (Olson; and Wiygul and Gifford). The evidence for living near a college or university being beneficial is contradictory (Wiygul and Gifford; and Roe and Roe).

Recommendations

Based on sound research, issues regarding the structure of a science fair can be determined. The areas that have been considered are: 1) the type of project to be entered in the fair, 2) the determination of students who should participate, 3) the relative merits of competitive or non-competitive fairs, 4) the value of working individually or in groups, 5) the motivators offered and 6) the amount of work expected to be done outside of the classroom.

The Type of Project to be Entered in the Fair

It has been shown that inquiry is a valid method of instruction (Hofstein and Lunetta), and that students are capable of learning by inquiry (Cantu and Herron; Case and Fry; Kolodily; Bredderman; Novak, Gowan, and Johansen; and Novak, 1977), therefore it seems reasonable to expect students to do an experimental project as opposed to a collection or display. Based on the modified inquiry goal of Welch, et al., which points to the need of having different expectations for individual students, and the hierarchical nature of learning science (Tamir and Amir; Yeany; and Arzi and Ben-Zvi), it seems reasonable to have progressively higher expectations for each successive year that students participate in a science fair.

Who Should Participate?

It appears that all grade levels are capable of participating, if provided with adequate instruction. Success has been noted in teaching formal concepts to as low as the primary grade level students (Novak, 1977). One should not expect to see adequate results with brief exposure to inquiry, however (Daab). Teachers should be reminded of the complex nature of teaching the process skills and the need for all prerequisite knowledge to be in place (Tamir and Amir; and Yeany). Again, if expectations are adjustea to meet the individual student, all students can participate (Welch, et al.).

Should the Fair be Competitive?

By definition of fair in the American usage, this type of event is typically competitive (eg. county fairs). Research has indicated that the competitive structure can be an effective structure particularly in the area of science (Okebukola and Ogunniyi; and Olebukola). To reduce anxiety where using the competitive structure, clear goals should be established (Johnson and Johnson; and Tjsvold and Marino).

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Should Students Work Individually or In Groups?

The cooperative structure has been shown to: be prefered in inquiry learning (Tjosvold and Mrino); promote positive attitudes (Humphreys, et al.); and be the most effective structure for the majority of students when paired with competition (Okebukola). It has also been shown that the individualistic structure is very effective in the competitive structure especially for high ability students (Michaels). The individualistic structure may also be desirable if one of the goals of the school science fair is to select a winner to go on to another competition that accepts only individual efforts. Since the cooperative structure is the most effective for the majority of students, and the individualistic structure the most effective for only the high ability students, who would in all likelihood be the "winners" to go on to another competition, it seems reasonable to allow both individual and group projects.

Motivational Structures

Without a doubt, clearly stated goals must be provided to students. This will not only lessen the anxiety associated with the competitive structure (Johnson and Johnson; and Tjosvold and Marino), but clearly stated goals have been shown to improve student performance as well (Schunk; and Rosswork). Rewards should be offered especially if students work in groups, since it was shown that the students that worked in groups but received no rewards learned significantly less than students working together for a team reward (Slavin). Rewards that are perceived desirable by the students must be selected carefully (Maheady, etal.; and Bebeau and Sullivan); should not be money (Deci; and Rosswork); and could be in the form of social approval (Deci).

Working Outside of the Classroom

Student projects can be expected to be of better quality if they work on them outside of the classroom (Keith; and Tamir, 1985). Teachers do not need to be concerned about students receiving too much help from parents since most parents do not check homework (Tamir, 1985) and most winners have reported very little parental involvement (Olson; and Wiygul and Gifford). Teachers should not hesitate to encourage students to enter sophisticated science fairs despite the lack of availability of college or university facilities since evidence has been shown that this is not essential (Roe and Roe).

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