First Activities of the Physics Kind: Physical Science Activities for the Primary Grades

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Introduction

Women and minorities, except for Asian Americans, are under-represented in the physical sciences and technical trades. These students tend to avoid physics, chemistry and technical courses in high school because they fear that they cannot "handle" the subjects covered. In addition, recent studies by national organizations have demonstrated general weakness in the physical science training of students in the United States, particularly when they are compared to their counterparts in Japan, China, the Soviet Union and other industrialized nations. This project applies to the physical sciences some of the techniques developed by EQUALS to encourage participation of women and minorities in mathematics. While many mathematics skills such as problem solving and measurement are common to mathematics and the physical science, science instruction also depends on the acquisition of content and the construction of an intellectual framework which can organize it. Therefore the methods which have proved successful in EQUALS in mathematics must be modified for use in science instruction.

The EQUALS program of the Lawrence Hall of Science at the University of California at Berkeley has a successful record of developing instructional activities to encourage the participation of women and minority students in mathematics where such students are traditionally under-represented. The EQUALS activities are designed both to remove the fear of math which women and minorities develop early in school and to build math skills such as spatial perception and logical thinking in which test results show women and minorities are weak.

Physical Science in the Elementary Classroom

The contents and vocabulary of the physical sciences are no more intrinsically difficult than those of biology and earth science yet few elementary classrooms stress them. There are three basic reasons for the conspicuous absence of physics from elementary classrooms. First many materials are designed by university professors of physics or science education who have little feeling for the skills, interests and attention spans of second graders. They tend to overestimate the time and resources available to the primary teacher who must cover not only science but also such vitally important subjects as mathematics and reading. Secondly many proposed physical science activities require supplies and equipment that are difficult to obtain and beyond the budgets of elementary schools. Finally many elementary teachers themselves fear physics and feel uncomfortable trying to teach it.

Introduction of physical science in the early grades will help to improve the physical science backgrounds of all students and to reduce the barriers of fear that prevent their enrollment in high school physics, chemistry and technical courses. If the physical sciences are familiar subject matter to female and minority students, they will be more likely to study them. Increasing coverage of relevant skills and concepts in the early grades will

improve the level of physical science knowledge and skill among all students. Finally physical science provides many opportunities for introducing concrete illustrations of mathematical concepts and processes. Its early introduction thus reinforces mathematics education in these grades.

The dependence of science on both content and process puts science education, particularly in the early grades, between the Scylla of over-dependence on process which characterized the "discovery" method materials and the Charybdis of books which merely describe phenomena or introduce students to clever experiments with no attempt to construct an intellectual framework which will later form the backbone of the quantitative formulation of the physical sciences. For this reason, EQUALS science materials are designed in sets of activities which should be done sequentially in the classroom. The activities build necessary skills such as measurement and description and at the same time attempt to develop the framework by which the various contents of the different activities are related to each other. For example, the sequence of activities on motion described here first introduces the measurement of time and distance. Then the idea of direction in motion is added followed by the idea of speed which relates distance and time. Velocity relates time, distance and direction and is logically the next topic to be covered. Finally the sequence will introduce the idea of acceleration which is a change of velocity with time. This has been done in two steps: the change of speed with time and then the change of both speed and direction with time. Clearly second grade students cannot understand the quantitative relation among the various quantities, but the idea that they are related in a systematic manner can be taught early. The early introduction of technical vocabulary will also make later instruction in the physical sciences where students are also expected to grapple with mathematics less intimidating for them.

This project has designed activities to introduce the physical sciences in the elementary classroom. They have been developed by a second grade teacher and a university physics professor and tested on real live second graders in order to produce technically accurate materials which are of practical use in the elementary classroom. This project was funded by a Providing for Potential Grant from the Wayne Township School Corporation and money from the Carnegie Corporation of New York granted to the EQUALS Program at the Lawrence Hall of Science of the University of California at Berkeley.

Types of Activities

Stations are instructional activities which can be easily set up in the classroom for students to explore when they are early or have finished other work. In the EQUALs mathematics program, stations have been developed to teach important mathematics skills such as spatial visualization or problem solving. These activities are popular with both students and teachers and seem to be successful in teaching the skills they are designed to strengthen. This project has extended the use of stations to teach basic concepts in physics in the early grades. Since physical science concepts build on one another, it is logical to design stations as units which combine to present one set of ideas. The stations should be set up or done in sequences which will give the student a grasp of the skills and contents of one area of physical science. All stations have been designed for use in the very early grades. No expensive apparatus is necessary. Materials have been designed for easy use by the teacher. Wherever possible, the teacher only needs to xerox station materials. Use of these stations does not require that students understand every implication of the concepts presented nor the full meaning of the technical terms used, but by an early encounter with physics will reduce eventual fear of the subject and use of the jargon will give the words a familiar ring in students' ears. Stations use only one set of supplies and equipment for an entire classroom. They occupy little space and can be set up easily in the absence of any sort of laboratory facility.

Elementary children are often kinetic learners. Fortunately many concepts in the

physical science lend themsleves to instruction as active games. Whenever possible, concepts have been packaged in the form of active games which will introduce skills and processes that will be re-enforced by station sequences. For example, the concepts of speed, velocity and acceleration are particularly ammenable to instruction by means of games. The teacher may use the games to explain concepts and skills which will later form the basis of station sequences.

The Motion Sequence

These seven stations deal with the description of motion in the jargon used in physics. Wherever possible, the station designed for use in the classroom has been backed up with a playground game which presents the same concepts.

The description of motion begins with the idea of measuring distance and time. The stations can begin with Zoo Secrets and Timely Turnup. These two stations introduce respectively the ideas of measuring distance and measuring time. Students are encouraged to experiment with the activities described in the Timely Turnup and to try the measurements in Zoo Secrets until they are comfortable with the measurement of space and time. Extra games have been created in each set to provide students more practice.

Zoo Secrets are animal picture puzzles that hide words which sometimes are used to describe motion. The child is given a ruler, the puzze picture and a set of cards with measurements on the front and a letter on the back. To find the hidden word, the student measures the lines of the picture in the order in which they are numbered and places the measurement cards in the correct order. He or she then turns the cards over and discovers the hidden work. The words are the physics terms used to describe motion and will probably be unfamiliar to second graders. The teacher should help the student pronounce the word and call his attention to the hint on the picture puzzle which defines the hidden term for that puzzle.

In the physical sciences, distances are usually measured in the metric system. In these activities, this is done simply by using centimeters as a matter of course rather than talking in terms of changing from inches to centimeters. Since young children are not familiar with measuring in inches, the use of centimeters will probably bother them less than it would older children. The teacher shows the children how to use a ruler and then lets them try Zoo Secrets. This station could also be done as an in-class activity with each student working on one of the puzzles at his ownd esk but this uses valuable class time. Stations teach during extra moments during the day.

Timely Turnups is an exercise in the measurement of time. The puzzle board asks questions answered by measurements of time such as "How long does it take to skip across the room?" The student is given a deck of puzzle cards with times and letters on them. He or she chooses the card with the appropriate time and places it over the question is answers on the puzzle board. The letters then spell out a physics term used in the description of motion.

The data used in the puzzles will obviously have to be adapted to different classrooms since it will take varying amounts of time for children to run across different rooms. Children should be encouraged to experiment and time themselves to see exactly how long it will take them to run or crawl across the room. This provides practice in measuring time as well as in conducting an experiment. The teacher should encourage students to try the experiment by simply answering the question "How long does it take to crawl across the room?" with "Why don't you try it and see?" Part of the point of the exercise is to give students a feeling for how long times are. A second is the standard unit of time in the physical sciences and is therefore used here although it is shorter than that with which most young children are used to dealing. As in Zoo Secrets, the vocabulary words hidden in the puzzles have value in their own right and attention should be called to the meaning of the hidden words although students may not remember them.

The next staion in the sequence, Treasure Hunt, introduces the idea of direction into the concept of moti on. The station is played on a map of a treasure island on which is a numbered grid and the outline of a compass. The student is given directions from a landing in terms of number of boxes to move and the direction in which to move. The directions lead to the squre under which the "treasure" is buried. As the student searches the grid for the treasure, he/she learns that the direction in which one moves is as important as the size of the motion. If the teacher wishes, he/she can provide the student with a sticker or some other treasure when the student is successful in the game. The concept of direction is basic to introductory physics and often is neglected until the student enters high school science. Treasure Hunt attempts to introduce it earlier so that the use of co-ordinates is not a culture shock to the older student. This activity can be done as an in-class activity with each student provided with a copy of the map and a set of co-ordinate clues.

The Animals' Race introduces the idea that speed measures how much distance is covered in each second. This is the second step of the structure of ideas used to describe motion in general. It introduces the idea that you need a relationship between time and distance to describe motion. The teacher can demonstrate this very easily by walking slowly across the classroom and then walking the same distance quickly. Ask the students what was different even though the distance you covered was the same. In real life, the unit of time is generally the second and the unit of distance is the meter. In the station, one turn is the unit of time and each animal can cover a set amount of distance in each turn. That distance is determined by the length of the cardboard strip associated with that animal. Moves are made in turn along paper race track by turning the strip over and moving one length each turn. The students quickly learn that the rabbit wins every time if the animals move only in one direction because it has the longest strip. They get bored with this game quickly.

To use the activity as a learning game, the teacher designates a race track on the playground or in the classroom and the children choose who will represent each animal in the game. The different animals can take different numbers of steps each turn. For example, a rabbit might take five steps while a turtle can only take one. You can make up your own cast of animals or follow the suggestions of the stations. The children may prefer super-heros to animals. Let the children run a few races. Of course, one child always wins and the teacher should point out that that is because he or she covered the most distance during teach turn. This sounds terribly obvious but many college freshmen have real trouble grasping it when it is written down in math terms.

The Confused Animals' Race introduces the idea that direction as well as speed is important in getting to a finish line. This is the physics concept of velocity which is the speed of an object and the direction in which it moves. The Confused Animals' Race involves moving the animals at a set speed by turning strips as was done in the Animals' Race. Each animal is allowd to move a fixed length each turn. This time the animals don't move straight toward the finish line but can go in any direction. The students spin a direction spinner to find out which direction they will move in each turn. This time the fastest animal does not always win. It depends on the direction in which the animal moves. Associated reading is clearly Aesop's fable, "The Tortoise and the Hare" since the lesson obviously applies.

The Confused Animals' Race is also easy to present as a physics game. As for the Animals' Race game, the teacher must designate a race course on the playground or in his or her room. The starting point should be near the center of the course. On the playground, a basetball court works well with a finish line at one end of the court and a starting point near the center. The children again select who will be which animal and the teacher specifies the speed at which that animal can run, that is the number of steps

it may take during each turn. If the chilren have played the Animals' Race, they will all want to be the fastest animal which won that race. Each animal will choose a partner to spin the spinner for him or her. To play the game, the animals start in the starting box. The partner spins the spinner and the animal moves his appropriate number of steps in the direction that the spinner shows. The animals take turns moving. If an animal runs off the race course, he loses a turn. The winner is the first animal to cross the finish line. Obviously the fastest animal will not always win this race. The teacher should stress the importance of direction as well as speed in determining the position where the animal ends up. If the teacher uses the word velocity to describe the animal's speed and the direction in which it goes, the children will not understand the word in detail but they will soon associate it with speed and direction.

It is very important to start even very young children working with direction since it is central to beginning physics in high school. It is a hard concept in the abstract and it will be of real use to students if we can find a way to make them instinctively comfortable with it. Students should do The Animals' Race before they try the Confused Animals' Race. The other essential concept in The Animals' Race is change. Most mathematics and science activities stress the total value at which we arrive but physics deals in the discussion of changes. Whenever possible, the teacher should talk with students about how much the animal's position has changed and how fast it has done so.

The final concept in the series is acceleration which is the change in velocity during each time interval. Acceleration is the final step in the description of motion since it involves measurement of distance and time, direction, speed and velocity. Velocity can change when an object speeds up or slows down or when it changes the direction in which it is traveling. Traffic Jam involves acceleration by increasing or decreasing speed. The players are cars trying to reach the end of several blocks in a traffic jam. They take turns rolling a die to determine how many blocks they move in that turn. The teacher should point out that this game is different from the Animals' Race because the players travel different distances each turn instead of always going the same distance each turn. Probably this will strike children as terribly obvious but it is important to start them thinking about the way in which they change the number of turns it takes them to reach the end of the board. On the playground, the board is the course used for the Animals' Race which now represents a busy street. Players are cars and roll a die to see how many steps they are allowed to take each turn. The first player over the finish line wins.

The Elastic Legged Pirate can change both his speed and the direction in which he is traveling. The game involves both a spinner to determine direction and a die to determine how many squares the pirate can move in one turn. It will probably work better if the students have tried the Animals' Races and Traffic Jam first. Each player takes a turn spinning the spinner and rolling the die. He moves the number of squares on the die in the direction shown by the spinner. If he goes off the board, the student loses a turn. All players start at the landing and the first player to reach the treasure wins. In this game, you will need to mark the spinner so that the players move north, south, east or west or on one of the diagonals. This will help to prevent confusion on how to count squares for each turn.

The Elastic Legged Pirate can be played as a game on the same course as the Confused Animals' Race except that the players now need to reach a special region of the course where the treasure is hidden. In this game, each pirate will need a partner. The partner spins a spinner to see in which direction his or her pirate will travel and also rolls a die to see how many steps the pirate can take in each turn. Thus the pirates will travel in changing directions and at changing speeds. The teacher should use the word acceleration to describe a change in either a pirate's speed or the direction in which he or she is moving. To play the game, the pirates take turns starting in the starting box

and moving the required number of steps in the direction the spinner tells them to go. If a player runs off the course, he or she loses a turn. The first pirate to reach the treasure wins.

These activities complete a very solid framework for describing motion. It is the basis of the first several weeks of a high school physics course which simply does the same thing in terms of mathematical formulas. Second graders will not have much feel for numbers and certainly not for formulas but these exercises should give them a feel for the relationships involved and how changing time or distance affects other quantities like velocity or acceleration. Just a feeling for the involvement of direction in motion should help students get a feel for beginning physics. Hearing the vocabulary will make it less intimidating for students in more advanced science courses. The intent is not to transform second graders into physicists or even to provide them with a technical vocabulary for describing motion but to give them an early encounter with the relationships involved and a feeling for the vocabulary and concepts used. In addition to describing motions around them, they will begin to construct a conceptual framework upon which they can later hang numbers.

Needless to say, the conceptual design of the stations and games changed as they were tested on a lively group of second graders at Westlake Elementary School. The games were not in the original project design and were added to help kinetic learners understand the concepts presented. Two stations were added to the original five (Traffic Jam and The Elastic Legged Pirate). Mechanisms for the teacher to introduce the concepts to students before they encountered the games were developed after initial confusion resulted in some of the stations. A set of teacher notes was prepared to give the teacher some written words to describe the materials. The formats of the activities themselves were modified to a form suitable for use in the elementary classroom. Boards became simpler and instructions were written so that second graders could understand them. Expected problem areas did not materialize. For example turning the cardboard strips used in the Animals' Races was not difficult for the children. On the other hand, unexpected problems materialized. For example, the Elastic Legged Pirate couldn't be taught as it was originally used because it added the concepts of changing velocity by changing speed to the concept of changing velocity by direction. Traffic Jam was introduced as an intermediate stage. The materials still have unresolved problems. We would like to include greater emphasis on career options and the importance of staying involved in science in the sequence. A pre and post test sequence has been developed but has not yet been tried on students using the full station sequence.

At the time of this writing, the sequence shows promise of offering a workable introduction to the study of motion in the second grade. Classroom observations indicate that students who have used the activities seem to grasp the concepts presented and enjoy the activities. Their favorite activity was overwhelmingly Treasure Chest, perhaps because the teacher presented them with a real treasure from a cardboard treasure chest when they got the correct answer to the puzzles. On the basis of our observations, we feel students learned the most from Elastic Legged Pirate since they had to understand and to some extent synthesize the materials presented in the other activities in order to understand this final game. The materials on motion are approaching a final form and we hope to continue the project by developing other first activities of the physics kind.