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Using Hands-On Manipulatives to Teach Problem Solving

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USING HANDS-ON MANIPULATIVES

TO TEACH PROBLEM SOLVING

Thesis Presented

By

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USING HANDS-ON MANIPULATIVES

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A Thesis Presented

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ABSTRACT

USING HANDS-ON MAINIPULATIVES

TO TEACH PROBLEM SOLVING

September, 1996

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As educators we share a link with the classic story of the "Velveteen Rabbit", as we also seek what is real. In education "real" is what holds meaning for the students and connects their world to the world of the classroom. As teachers we continually ask for the students' active participation, involvement and commitment to the learning task, but too often we teach only from the textbook. Classroom tasks that do go beyond textbook mastery may spark the students' interest, but sometimes appear to have no link to the reality of the students' world. Cognitive research reminds educators of the importance of making learning connections as a means of preventing knowledge from becoming inert.

This thesis proposes a model that attempts to offer students a curriculum that's 'real' for the students. The model emphasizes the critical and creative thinking skills used in problem solving, while it draws on the strengths of two programs, problem based learning and LEGO Dacta bricks.

The problem based learning model stresses the problem finding component of the problem solving process, and the LEGO Dacta emphasizes the solution finding and solution testing phase.

Problem based learning begins with offering the students an ill-structured, researchable problem to solve. The students' goals are to determine what information would be needed to define and ultimately generate a solution. Since the problem finding phase in problem based learning offers many, varied approaches to the problem, the students may define the problem in a way that is unique to their point of view. This differs from the traditional problem solving approach, in which the students are given a well-defined problem. By allowing the students to determine the problem to be explored, they are able to assume ownership of the problem.

LEGO Dacta bricks are one of basic building toys of children. Introducing building blocks into the problem solving process combines the world of problem solving with the students' world of play. The students are more eager participants in the process, as they can formulate a concrete model to test and evaluate their solutions.

The goals of this curriculum are three-fold: 1) to have the students become more involved in the learning task; 2) to teach the students the steps of the problem solving process and to transfer that knowledge from the

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CHAPTER I

INTRODUCTION

"All students should define, analyze and solve complex problems." (Massachusetts Department of Education, 1995, 8)

The model proposed in this paper is an outgrowth of having used many, various problem solving models with students in the elementary classroom. Teaching in a Gifted and Talented Program in Plymouth, Massachusetts, I have had the opportunity to work with students in both the regular classroom and students who have been identified for a gifted program. The primary goal of the curriculum used in Plymouth is the teaching of critical and creative thinking skills for all students in grades four, five and six. A great deal of my teaching time is directed to teaching the process of problem solving.

Within the wide variety of problem solving models I have used with students, I have found that all of the models teach the steps of the problem solving process. There is a consistency of approach within the models', most depend on the same five steps: define the problem, explore alternative approaches, determine criteria for evaluation, select the solution, develop an action plan. Various models may differ in the development of these five components, but all models appear to maintain some form of these five steps.

Since all of the various models have a similar foundation for solving a problem it is interesting to observe the different reactions' students have to the models. In some cases, the students are eager participants in the problem solving process, while with other models I have found that the students are reluctant and show little if any excitement for the process. The students' degree of participation does not seem dependent on whether the lesson is given to the students in the regular classroom or to students in the gifted program.

The question is, why are the students more actively involved in one approach than in others, if the content taught is similar? In exploring the various approaches, I discovered that the students are more involved in a model that allows them to test their solutions. They are eager to demonstrate their knowledge by constructing a model, creating a skit or designing a picture to illustrate the final solution. In problem solving that involves a hands-on solution, the students' questions usually begin with "can we ...?" This question gives the teacher an indication that the students have begun to explore the assignment and are ready to make some self-directed decisions about the problem. This type of question is in sharp contrast to problem solving models that required written solutions. Using these approaches, the students reacted more passively to the problem solving process. They would wait for the teacher to give directions, which would usually begin with "now you will ...".

Considering these observations the author began to teach the problem solving process that provided the students with hands-on opportunities to the models. In some cases, the students are eager participants in the problem solving process, while with other models I have found that the students are reluctant and show little if any excitement for the process. The students' degree of participation does not seem dependent on whether the lesson is given to the students in the regular classroom or to students in the gifted program.

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Considering these observations the author began to teach the problem solving process that provided the students with hands-on opportunities to test their solutions. By using problems that allowed the students to create concrete tests of their solutions, the students became eager participants involved with the solution finding phase. I realized that although the students were quite involved with the solution testing, they were not as involved with the rest of the process. The steps of the problem solving process needed constant reinforcement and little of the process was retained from one lesson to another. I found that the students would rapidly go through the steps of the process to reach the solution testing phase. I began to wonder how to keep the involvement of the students, and still help them assimilate the steps of the problem solving process? The students needed to be as involved in the problem finding as they were in developing the problem's solution and in testing it.

At this point I began to work with a model called problem-based learning. It differs from most problem solving models in that it begins with an ill-defined problem or a problem that still needs to be refined. The students are given a situation that contains a problem. Before being able to create a solution to the problem the students must first structure or define what problem they encountered in the situation. The development of the problem statement may vary from student to student depending on how each views the problem situation. An example of this type of situation might be a futuristic look at the exploration of space. The students' problem might be: 'A colony is being established on a newly discovered planet, what are the many, varied and unusual problems the team of space explorers might face?' Since this situation begins as an ill-structured problem, it forces the students to engage in problem finding, to define and structure the problem. Problem based learning, also, uses problems that might be encountered in the real world. For example, many design and invention problems are used. By giving the students a real world problem, they are able to develop, research and gather information about the problem. The open-endedness of the process of problem based learning means that the students have control of the entire process from problem finding to problem solution. The role of the teacher is primarily to function as a coach or instructional guide through the process.

Problem based learning seems to answer the question of how to get the students through the steps of the problem solving process, but it still only uses a written rather than a hands-on solution. From my previous observations, the students in the elementary grades needed to become more involved in the development of the solution.

I have been working with the material of the LEGO Dacta and LEGO TC Logo for a number of years. The material provides the students with a hands-on approach to problem solving. The LEGO bricks, gears, batteries, motors, etc. offer the students the tools of our modern technology. By linking these LEGO building blocks together the students are able to construct and test their solutions to a variety of problems. In one class, a group of students designed a new type of pencil sharpener. Although their results successfully simulated their solution design in testing the model they found it was not able to sharpen a pencil. The results forced the students to reevaluate the solution they had designed.

The LEGO bricks offer the students the material to become the architect of their solution. The solution is no longer an unrealistic speculation, but a functioning idea that must endure the rigors of realistic testing. The students can dream the solution and seek to turn that dream into a reality. In some cases, solutions must be modified to fit the criteria of the environment they are to function within. The hands-on manipulatives of the LEGO Dacta system offers a concrete tool to investigate modern technology and the problem solving process. The incorporation of the LEGO Dacta system with the problem solving process offers the students the opportunity to concretely understand the implications of their solutions.

In the past, I have used LEGO bricks to allow the students to explore and master various math and science skills. The format developed by LEGO was well defined. A recommended introduction of a simple machine, for example, would give the students the building card with instructions on how to build the machine. This procedure was structured to help the students understand the concepts of math and science. The type of problems given to the students are generally well-defined with usually only one possible answer. The material follows a more traditional approach of teaching to achieve the one correct solution.

The premise of this paper is that the combination of problem-based learning and hands-on manipulatives, such as the LEGO Dacta material, will answer both the need to have the students understand the steps of the problem solving process and the need to get the students actively involved in testing their solutions. The students are able to use the LEGO bricks with ill-structured problems to create models of their solution, thereby emulating closer the behavior of a scientist or engineer.

The goals of this combined approach are in concert with my professional beliefs. I believe that 1) All children's learning is maximized when they are actively involved in the learning process. 2) Children's learning is enhanced when they are allowed to do work that they have devised. 3) It is more important to teach children the process than to memorize the content. 4) All children are capable of learning and applying higher order thinking skills.

This paper is divided into two main sections. The first section provides the reader background material in how to use the LEGO building material in the elementary classroom. In addition, this section, also reviews the research on problem-based learning and the functionality of problem-based learning in the classroom.

The second section of the paper outlines my program of combining problem-based learning and LEGO bricks into a lesson framework. As the material is used in a very open-ended format, the lesson is just a guide, rather than a step by step procedure. The proposed program hopes to transforms the classroom into a space where students are able to become the architects of the lesson and the teacher becomes the instructional coach. A flow chart of the problem solving model used in this program is found within this section and demonstrates how it can be used in the classroom. This program will illustrate a problem solving process, that is not a step by step sequence from problem defining to problem solution. The flow chart shows a recursive pattern of reevaluating, retesting and redefining within the problem solving process. The problem solving process proposed is meant to allow the students the opportunity to modify and improve their solution design.

Establishing the appropriate classroom climate and transforming the teacher's role are central to the process of problem based learning. In chapter III, I recommend techniques for establishing the 'thinking classroom' and for the teacher to become a metacognitive coach. This section stresses the importance of transferring the responsibility for the learning from the teacher to the students. The goal is the development of the students as independent learners and active participants in the learning process.

CHAPTER II

BACKGROUND INFORMATION

LEGO Dacta and LEGO TC Logo

The LEGO Dacta material is a construction set using plastic interlocking bricks, that joined together build models and demonstrate simple principles of physical science. Using this material students are given the tactile experience of demonstrating their understanding of basic science concepts and principles. The material is presented to the students in kit form and each kit includes, gears, motors, various sizes of building bricks, axles and both light and touch sensors. (See appendix A) The students can use the material to build a variety of simple machines. They can follow the detailed building instructions that are included with the kits or they can create their own designs and inventions. The LEGO bricks are flexible enough to allow the students to build most of the inventions they design.

LEGO TC Logo is the connecting link to the computer and for most elementary students their first encounter with computer programming. The students are able to use the LEGO bricks to construct their invention and the Logo language to program their invention to move or react to the environment. One example is a group of students who decide to built a stop light to help direct traffic. The motor regulates the ability to turn the light on and off and by using the Logo computer language it is possible to program the light to operate with a series of flashes. By connecting the LEGO motor to an interface box the students are able to write programming statements and have the computer run their project.

The use of sensors allows the students to program the computer to react to information from the environment and to generate specific output based on what they want the machine to accomplish. For example, the students built a car and put the touch sensor on the front, if the sensor is activated the child can program the car to turn right or left. As in this example, some elements of programming can be very similar to some aspects of a simple logic course.

LEGO kits can be shared by one to four students in a classroom. The team approach allows the students to share ideas, problems and solutions while strengthening the cooperative skills of team building. The students enjoy selecting a group name and in an effort to form a real world experience, are asked to model their group after a design team for a major company that would be facing this problem.

Enthusiasm is the first building block of the LEGO curriculum. A majority of the students bring to the lesson a natural love of construction tasks and the youthful energy needed to explore and create. The use of LEGO bricks in the classroom captures the students' attention and keeps each interested and focused on the task. Students who become frustrated easily are able to risk failure and keep working to solve a problem that requires them to construct a product. The ability to involve the students with the material is what keeps them creating, and inventing throughout the problem solving process.

I have used LEGO bricks with various students; students who get straight A's, students who will tell you they 'hate' science and math, students who have learning problems, behavioral problems, motor problems, girls who state that 'working with LEGO bricks are just for boys', and teachers whose teaching methods are didactic. From these very diverse groups, most students want to 'play with LEGO'. No matter what entering behaviors the students start with, the vast majority would ask to have the LEGO bricks brought back repeatedly to their classroom. Teachers would say that teaching mathematical concepts like ratios, averaging, graphing, and fractions was faster and easier. The primary reason for this rests with the students' need to create and invent. Not only do students learn math, but science, social studies, research, and language tasks are also incorporated into their activities. An example would be the students who built a simple machine to help the children cross the street in the sample introductory lesson. The students needed to understand how gears operated in simple machines, the math of gear ratios, they needed to research various models of their machine, and were expected to keep a written inventor's log, in addition to presenting their project in an oral report.

Combining the LEGO Dacta with the computer and the language of Logo will add to the type of task the students can be working on. The computer programming adds the dimension of logic, codes, artificial intelligence, and robotics. The experience of working with LEGO bricks demonstrates the power of this tool in creating an environment where self-directed learning can evolve. LEGO TC Logo gives the students the opportunity to combine creativity and science. Creative exploration is encouraged in art and creative writing, but has often been excluded from science and thus the opportunity to develop a bond between children and science is hindered. (Papert, 1993)

The students are able to personalize the LEGO program creating and designing their own learning environment. In part the students may not see LEGO bricks as the standard curriculum and they may know that paper and pencil tests could not be used to measure their performance. LEGO bricks are viewed as play toys, but as educators we know that they offer the child a tool to learn and grow.

The Problem Solving Process

According to Matlin, a problem consists of three components, the goal state, the initial state and the rules. The rules are the procedures and the restrictions that need to be followed in order to get from the initial state to the goal state. (Matlin, 1993) A number of teaching strategies have been submitted as heuristics to help the students understand and develop an approach to solving a problem. Most strategies contain the following steps, finding and defining the problem, exploring alternative approaches, evaluating possible solutions, selecting a possible solution and applying the solution to the problem by developing a plan for implementation of the solution. (Hoover, 1991) In teaching the problem solving process, the heuristics and components, are useful to the problem solver, but what impact does this types of problem have on the problem solver? Problems presented in the classroom are generally problems where a certain amount of content specific knowledge is necessary in order to reach a solution. They are, also, usually well defined problems where one right answer is needed in order to correctly solve the problem.

Most teachers agree that knowledge is important in education, but as any experienced teacher can confirm, tested knowledge does not guarantee that the student will utilize it when it is needed or be able to retrieve it after the testing situation. According to Bransford (1987) certain problems can be difficult to solve not because of a lack of knowledge, but because of a failure to transfer that knowledge. A failure to transfer relevant knowledge from one situation to another is a common problem in education. Alfred Whitehead in 1929 warned of the dangers of inert knowledge, or knowledge that is not accessible to the student, and of the practice of traditional education which produces knowledge that remains inert. (Bransford, 1987) As teachers we must somehow connect our students with the learning that occurs in the classroom. The students must be able to find meaning in what they are learning through the method used or the materials they apply to the learning task.

The students' ability to access and use information appropriately demonstrates the difference between having the students memorize facts and using the facts as a conceptual tool. Theorists, such as, John Dewey argue that students need to understand how new information can be used as a tool in order to make it easier for them to solve similar problems and transfer the learning to other situations. The reports of problems within the area of knowledge transfer come from many educational fields. For example, Alan Schoenfeld, a math educator, concluded that math instruction is "deceptive and fraudulent". (Schoenfeld, 1982, 27). He reported vast differences between what the math teachers thinks their students are learning and what in fact they are learning. One example of this is the study at the University of Rochester where 85% of the freshman class takes calculus. It was reported that students could perform on the test only because it was a carbon copy of problems they have seen before. The students were only applying a well-rehearsed schema and when given a pre-calculus version of an elementary word problem only four of out of 30 students were able to get the right answer. The results of the study showed that the students were not learning the higher math concepts, but only duplicating the computations of similar problems.(Schoenfeld, 1982, 37)

In teaching the problem solving process to students the instruction must result in a transfer of the learning; it must transfer to other problems and situations. The students' knowledge of the problem solving steps can not emulate the above example and remain applicable to just one situation, since problem solving is a life skill.

What is Problem Based Learning?

Within the past few years, problem solving has become an integral part of the thinking skill behaviors that most curriculums list and most textbooks claim to teach. Problem based learning offers a fresh approach to teaching the problem solving model. The development of problem based learning stems from the medical community, as it was developed initially for medical students (Aspy, Aspy & Quinby, 1993). The medical community wanted to give their students' experiences handling real-world problems that a physician might actually face on a daily basis. In real-world situations a knowledge base is essential, but a physician, also needs to apply that knowledge in order to effectively diagnosis and treat a patient.

The first work with problem based learning was done in the 1960's and 1970's at McMaster University in Ontario, Canada (Aspy , Aspy & Quinby, 1993). At McMaster, problem based learning focused on two main processes: 1) having the medical students in small tutorial groups; 2) providing instruction so students investigated real problems that occurred in the treatment of real patients. Students used patient records to determine a medical problem and devise treatment. The questions and concerns generated by the students became the content for the course. The main teaching method was small group discussions between the students and faculty. Research data was gathered from laboratories, libraries, and by interviewing medical doctors. The outcome of this program at McMaster's was the shift from the lecture hall format and from factual note taking to active learning with an emphasis on acquiring meaningful information to help solve real-world patients' problems. The instructor became only one of the resources available to the students, rather then the main source of instructional direction.

In the 1980's Harvard University's School of Medicine started a program called "The New Pathway" (Aspy, Aspy & Quinby, 1993)) This program created four societies of forty students each. Each society was further divided into small tutorial groups and each group used a problem based format. The goal of the program was to help the students become more self-directed learners.

Could the model established by the medical community be adapted to elementary education? Work is presently being done to adapt problem based learning to the science classroom in both the elementary grades and at the high school level. (Gallagher, Sher, Stepien & Workman, 1995). The purpose of this paper is to develop a model that combines problem based learning with the technology of the computer and the use of hands-on manipulatives.

By using the LEGO Dacta system the students have the opportunity to be involved in a self directed activity, and to complete their ideas by building and programming a working model to test their solution to the problem.

Using Ill-Structured Problems in Problem Based Learning

"Well evolved is half solved." (Schwartz, 1971, 347)

By using the construction capabilities of LEGO Dacta and the Logo programming language the students have an opportunity to explore the real-world and are able to simulate the work of engineers and scientists in the mechanical areas. Problem based learning presents the student with ill-structured problems in the same way that the world presents the adult learner with undefined problems. An ill-structured problem gives a realistic portrayal of the problem solving process and is the key element in problem based learning. An ill-structured problem differs from the well-defined problem of most science textbooks in four ways:

1. The initial situation lacks all of the information necessary to develop a solution or even clearly define the nature of the problem
2. There is not one right way to approach the task and solve the problem
3. The problem solver has the ability to change the problem definition as new information is added
4. The problem is similar to the real-world as you can select a decision from a realm of possibilities, but alternative solutions may be equally viable. (Gallagher, 1995, 137)

In working with ill-structured problems, the student is forced to work redefined, evaluated and tested. The students become self-directed and independent learners, who are empowered to approach a complex problem with confidence. The use of ill-structured problems offers the students a similar experience to the type of problems faced by professionals in their chosen field.

In a study by Gallagher, Stepien & Rosenthal the use of ill-structured problems is explored with gifted students in a school for science and math. Students were given a pretest consisting of an ill-defined problem and directions to outline the procedures they would take to find a solution. The experimental group became part of a course entitled Science, Society and the Future (SSF) which was designed with the following process goals: to lead students to discover the interdisciplinary character of real world problems, to require students to engage in the process of solving an ill-structured problem and to improve the student's problem solving skills. (Gallagher, 1992, 198) In a single-semester course, students were given problems that had not yet been solved by the professional community. The students were not given direct instruction in 'problem solving techniques', but were allowed to pursue the problem as they chose without 'how to' directions from the teacher. The teaching role was to comment on the thinking in the process not the specifics of the problem. The comparison group was given conventional problem solving training using a well-defined problem.

At the end of the semester a post test was given to both the experimental and comparison groups. Results supported the hypotheses that significant improvements in problem-solving schemes would be observed in students in the experimental class who used the ill-structured problems that would not be supported in the comparison group (Gallagher, 1992, 199)

The results showed that the students who had used an ill-structured problem demonstrated an improvement in their approach to problem solving. Using problem based learning that stresses the use of undefined problems and the LEGO Dacta system that allows for open exploration of hands-on manipulatives should enhance the student's problem solving skills while helping them to employ an independent learning style.

Problem Based Learning in the Classroom

According to the report, Science for All Americans, Project 2061:

> Students should be given problems---at levels appropriate to their maturity—that require them to decide what evidence is relevant and to offer their own interpretations of what the evidence means. This puts a premium, just as science does, on careful observations and thoughtful analysis. Students need guidance, encouragement and practice in collecting, sorting and analyzing evidence, and in building arguments based on it. However, if such activities are not to be destructively boring, they must lead to some intellectually satisfying payoff that students care about. (Rutherford, 1990, 188)

Can problem-based learning answer the need presented by the science community? Can the use of LEGO Dacta and the Logo programming language assist the learning process by offering an "intellectual payoff" that the student will care about? As adult learners many of us find that the process of learning is retained longer than the memorization of facts. Gaining information is important, but learning how to learn should be the major goal in teaching students to be lifelong learners. School is the arena where students learn the skills and methods to become effective learners. They need to acquire the foundation for learning during their early years, so that they will have learning options as adults. Facts and data are the first building blocks of the students' educational foundation, but the methods by which they learn are the footings upon which that foundation rests.

Problem solving is a lifelong skill that we as adults implement on a daily basis. Career opportunities may change as we approach the 21st century, our knowledge base will likely expand, the computer will probably be faster and dominate more of society, but no matter what changes are projected for the next century the need for effective problem solvers will continue. It is unlikely that the future will propose a problemless society, so in a world that changes constantly, the tools and skills that must be stressed in the classroom are those that offer the students the ability to solve problems. An effective learner must be a creative problem solver using organization and planning skills to structure the creative flow of ideas and thoughts.

The behaviors demonstrated by creative problem solvers are the qualities that the classroom teacher will want to instill in the students. Some of these behaviors should include: curiosity, the desire to question, a joy in figuring things out and seeking challenges, and the ability to act as independent learners rather then dependent learners. (Davis, 1992, 93)

One of the strengths of the LEGO Dacta program is that it provides the opportunity for the learner to become independent. The use of hands-on manipulatives give the students the impetus to reach beyond a dependent need of a teaching authority. The concept of play and the use of the computer turn the students into interested learners and generally into involved learners. The LEGO bricks remove the students from the barriers imposed by the standard textbook instruction of read and recite. The introductory premise is one of a playful task where the options are limitless and the outcome becomes less predictable. The LEGO bricks catch the students' attention and involve them in the task, providing the teacher with the environment necessary for creative problem solving to flourish and scientific investigation to begin.

The problem solving process used in problem-based learning bears close resemblance to the skills used in scientific research. The steps of the scientific process are outlined below:

- Think of a good or interesting problem
- Gather information about the problem
- Decide which experiments or observations would contribute to a solution.
- Perform the experiments

- Decide whether the results really do contribute to a better understanding of the problem.
- Communicate your results (Gallagher, 1995, 137)

The three features of problem-based learning are; 1) initiate the learning with a problem, 2) use an ill-structured problem and 3) have the teacher act as a consultant or facilitator. The link with the scientific process remains strong, the difference between them is the level of participation by the students. In problem based learning the students are active participants throughout the process. In the scientific process used by most teachers, the students use experiments to initiate the learning. The teacher generally sets up the experiment and outlines the sequence of steps the students take to complete the experiment. The students' role is not to initiate the learning, but to follow a set of directions. Most of us have sat through lab work in a science classroom where the scientific problem solving steps were clearly used, but as the learners we had no role in structuring the experiment. The process used in both methodologies is similar, but the difference is the level of responsibility given to the student.

Using a Jacob Javits Gifted and Talented Grant from the US Department of Education, the College of William and Mary and the Center for Problem Based Learning at the Illinois Mathematics and Science Academy (IMSA) created a series of units adapting science and problem based learning. They identified four areas essential to making problem based learning closely reflect the practice of science:

1. Focusing the problem around the instruction of a significant science concept and using the problem and the concept to help students investigate science content.
2. Providing opportunities for the learners to test their ideas experimentally or through fieldwork with data that they have gathered.
3. Providing opportunities for students to manage their own data and expand their ability to perform note-taking tasks.
4. Providing opportunities for students to present their own solutions, including the supporting data using a variety of formats. (Gallagher, 1995, 139)

CHAPTER III

THE TEACHER AS A LEARNING COACH

A key component in problem based learning is the role of the teacher. The classroom must be able to support the methodology of problem based learning and the development of students as independent learners. The teacher must become a facilitator and consultant rather then a figure of authority. In order for the students to experience a free exploration of ideas, a match must occur between the instruction and learning style.

The teacher's role in problem based learning is not to act as the expert or didactic instructor, but to help the students become critical thinkers and understand the questions they must ask in problem finding, information gathering and analysis. The students must become the questioners and be able to look at all of the possibilities and sort through all potential interpretations.

The teaching responsibility begins when the teacher poses an ill-structured situation to the students. The students work as problem finders trying to clearly identify the underlying problem or problems. The process of problem finding is usually new to most elementary students, as most classrooms are more likely to practice the process of finding the solution. The following summarizes some suggestions for helping students in the problem finding phrase.

1. Confront students with ambiguities and uncertainties.
2. Call for students to look at a problem from different psychological, sociological, physical, or emotional points of view.
3. Establish a set for examining information in new ways.
4. Structure the problem only enough to give cues and direction.
5. Reveal gaps in information; unsolved problems
6. Create or reveal mysteries.
7. Call for going beyond what is known about something.
8. Involve paradoxes.
9. Pose conceptual conflicts; juxtapose opposites.
10. Pose future projections. (Torrance and Safter, 1994, 10))

Simple strategies can be used to facilitate an environment where problem based learning will thrive. To become the catalyst or motivator in a thinking classroom, the teacher must work to continue to excite the students' curiosity for learning. The use of LEGO Dacta motivates the students to participate in a more open learning environment, but the teaching role must help to continue that interest and direct it towards a productive product.

Another hat that is worn by the teacher is that of facilitator or guide in the process. This can be difficult since the teaching role must change and the teacher must know when to guide the students and when to step back and allow failure to occur. In this case, failure does not mean a failing grade, but the opportunity for the students to discover that one method does not work. As adults we are allowed to learn from our mistakes, but many classrooms have not yet adopted the same objective.

The teacher must stress the needs of all students and encourage them to explore freely without fear of criticism from their peers. The students will need to learn respect for the work of other members of the classroom community. Simple guidelines should be established during the first few class meetings and immediate consequences need to follow if the rights of others are infringed upon. A class rule such as, 'no dumping', makes a simple statement that all can easily understand and follow. Students are not allowed to use words like, "that's dumb" or "what a stupid idea". It is a clear message that needs to be enforced. All students need the freedom to take thinking risks without ridicule, in order to grow into thinking adults.

The role of the teacher in the problem based classroom extends beyond the behaviors that are displayed, and, also needs to include the role of questioner. One of the key elements of the LEGO Dacta system is that it will capture the attention of the students, but it is left to the teacher to help the students understand the thinking process. The use of thoughtful questions can be crucial when the students are working in the problem solving process. Open-ended questions force the students to delve deeper into the process and to examine or defend their predictions, ideas and hypotheses. The teacher's persistent challenging is a critical component of the problem based curriculum, since it helps students to incorporate the notion that giving reasons is an important part of their role as learners. (Casey, 1994).

One tool which is useful to the teacher is a chart of the Types of Questions Used in the Socratic Method (Paul, 1987). This chart (See appendix B) helps the beginning teacher form questions, that will help the student analyze and evaluate the problem solving process. Questions are divided into the following categories; questions of clarification, questions that probe assumptions, questions that probe reasons and evidence, questions about viewpoints or perspectives, questions that probe implications and consequences and questions about the question. In problem based learning with LEGO Dacta certain questions will be more effective in getting the students to further explore their ideas. Some of the questions that seem to be most helpful include, "What else do you need to know?, Do you have any evidence to support that?, But if that happened, what else would also happen as a result? Is there an alternative possibility?, Can you define the criteria you used in your decision?, What assumptions have you made about your design?" (Paul, 1987, 97)

Asking the students even the most open-ended question is not the sole component needed to promote thinking. Students must be given the time to process and think about the question. Many thinking skills programs stress the necessity of using wait time. In the problem based classroom wait time is essential to create an open environment. If thoughtful, reflective responses are expected from the students than the teaching role must be supportive classroom, but the simplest guidelines are as follows: wait 3-10 seconds after each question to let the student begin a response and wait 3-10 seconds after any response before continuing the question or asking a new one. Avoid verbal signals either positive or negative and eliminate verbal rewards. (Fogarty, 1993, 107) Allowing for more than one possible answer will also, help the students realize that you are not looking for one right answer to any given question.

The teacher needs to act as an enthusiastic facilitator in the problem based classroom with students acting as peer coaches and sharing the role with the teacher. As the lessons presented in problem based learning tend to be open-ended and can be long-term, the students can easily become discouraged when their ideas need additional development time or do not work the first time. Small steps are cheered and even minor accomplishments need to be recognized. In many cases, changing the students' role to independent learner means that they receive less written feedback from the teacher. Students may be assigned five to six tasks a day in a classroom where dependent learning occurs and each of these tasks will be scored, graded or reviewed, therefore, the students continually receive feedback on their work. In a problem based learning environment, the students may be working on one idea for an extended period of time and evaluation may be weeks away. Recognizing each step or accomplishment serves two purposes, the first is that it provides feedback to the students on a regular basis, and it allows the other students the opportunity to share in the feedback. The second purpose is that students can network their ideas, because the accomplishments of one group may help another group with a similar difficulty. This sharing can be a very powerful tool, as the students begin to work together and help one another. One students' comment was, "I worked on that let me show you what we did". This collaboration reinforces the students' ability to self-direct the learning environment.

As a final note the role of the teacher in the problem-based classroom is as a non-judgmental observer. Not giving an opinion or value judgment can be a difficult task for the teacher to fulfill in the classroom. Students who are going to think on complex levels need to break the habit of depending on the teacher for the answers. The students must feel capable of guiding their own work and begin to view teachers as facilitators, not the keepers of all answers. Students, who develop independent learning skills, have not just mastered one task, but have developed a life long approach to learning.

CHAPTER IV

THE PROBLEM SOLVING PROCESS USING LEGO TC LOGO AND PROBLEM BASED LEARNING

> "Students learn best in an environment that acknowledges, respects, and accommodated each learner's background, individuality and gender." Guiding Principle III, Massachusetts Science and Technology Curriculum Framework (Massachusetts Dept. of Education, 1995, 4)

An African proverb states, "If a man is hungry you can give him a fish, but it is better to give him a line and teach him to catch fish himself".(Papert, 1993, 139) Using LEGO Dacta in the classroom allows the students to teach themselves how to create and how to solve problems. The flexibility of the material that is being used opens up a variety of possible approaches and methods to solving a problem. Using problem based learning prevents the 'cathedral model of education' where the curriculum designer is the knowledge architect who specifies a plan for placing knowledge bricks into children's minds (Papert, 1980, 207). Problem based learning allows the learning to occur at different times, at different rates and allows for the individualization of the learning task.

In designing lessons to incorporate LEGO TC Logo and problem based learning certain strategies need to be incorporated. The following is a summary of what a problem based lesson should include:

- development of the student's reasoning skills
- involvement of the student in the learning topic

- hands-on activities rather then direct instruction
- incorporation of the student's plan into the lesson
- permission for the students' to test and retest their own solutions
- help in realizing that success is not always achieved by creating one right solution (Casey, 1994, 143)

Students are the keys to the success of any lesson. In problem based learning the teacher establishes the framework for the lesson, but the students create the activities that drive the learning. Lessons are only a rough beginning, each group of students may use a similar plan, but carry it into a different direction. The following are some comments by grade 5 students who were involved in their first introduction to problem based learning with LEGO TC Logo.

> "When you look at legos you think, oh, they're a piece of plastic and when you put them together they connect. But that's not all lego's are. They're like brainteasers, they take your mind places. Of course they're easy to build with, but when you don't use directions you can make your own creations. You can solve problems with them. Maybe those solutions will one day be reality. I know when I work with them in class we don't just work in our mind, we have fun trying to solve problems. I know before I used Legos in class I had a different perspective on legos. I thought 'oh great' (sarcastically) , but now I know they're more than that and I hope you do too.
>
> "I think Legos are awesome. They are a fun way to help you solve problems and make you think".
>
> "Legos are great for engineering skills, prototypes or models and building your imagination."
>
> "I wasn't really interested in Legos, but now that we use them in class they are fun. I love the way they work and fit in with the computer."

A common factor in the LEGO model is the involvement of the students with the material. In using this material for seven years I have found that most students are enthusiastic and eager to use the LEGO bricks. Even students who have never constructed with LEGO bricks seem to love the change from the standard classroom tasks. Most educators are aware that to capture the students' attention is essential to teaching and learning.

The teaching guide published by LEGO Dacta does address problem solving, but the students are generally given a problem with a known solution. The students then construct a model by following a specific sequential set of directions. The directions further guide the students in the computer programming to test the solution. The students tend to dependent on the instruction guide for problem solutions, rather then creating their own possible solutions. This method does allow the students to discover basic science and math concepts, such as, how a gear operates, or how a transmission runs, but it does not allow the students the freedom to play with their own ideas and solutions. In the LEGO teacher's guide the students are assigned a given set of parameters, in contrast to allowing them the freedom to develop their own criteria. The LEGO teaching model distributed by the LEGO company is easy for a new teacher to learn and offers a simple formula approach to teaching the material. The material may capture the students' interest, but it allows for little flexibility in exploring beyond the printed instructions. It tends to inspire a lecture format with all students working on the material in the same exact way. By not using the instruction guide and changing to the use of ill-structured problems both the students and the teacher are forced to look for alternative solutions and an alternative approach. Each group of students builds something different and is allowed to exercise the freedom to create, dream and self-direct the learning environment.

A basic tool of problem based learning is the 'Need to Know' board, Gallagher, 1995) which aids the students in formulating the problem and acts as a record of the students' progress through the problem solving process. Students refer to the 'Need to Know' board on a regular basis adding information and additional questions they might need to know about to solve their problem. As the board relates to each group's problem, the information on the board will be unique to the problem identified by the group. The 'Need to Know' board asks three basic questions: What do you know about the problem situation? What do you need to know about the problem in order to solve it? How can you find out what you need to know? These questions set up the first outline and create a priority list for the students to work with in defining the problem. Brainstorming in each area creates an active list of what is happening and what steps are being used to solve the problem. As each area becomes clarified, issues are removed from the 'need to know' column and replaced with new questions. The board becomes an active tool, which helps the students organize their thinking. Using the 'Need to Know' board easily leads the students to redefine and revise the problem as the section, What do you need to know?, expands. The problem solving process became an ongoing cycle of gathering information, testing options and revising.

The Thinking Skills

"We have in our thinkery, a well exercised power to think ourselves out of trials and difficulties." F. Robley Feland (Flack, 1989, 62)

Problem based learning utilizes the same format created in the model that is used in the Osborn and Parnes' creative problem solving process. The model identifies key components in the process and outlines deliberate steps, in order to facilitate an effective pattern for thinking in problem solving situations (Parnes, 1975). Although there are various formats to the Osborn and Parnes' model with a variety of labels, the sequence of steps ultimately remains the same. The students' ideas flow through the process of divergent and convergent thinking, as they seek to find an answer or solution to an ill-defined problem.

Students using the creative problem solving model approach a problem by seeking alternative solutions via idea generation and the critical analysis of the background information related to the problem. The methodology uses both divergent and convergent thinking and provides a means to broaden the possible solutions and alternatively to evaluate them using criteria generated from the problem statement. The continual flow of ideas, from seeking a broad range of ideas, to one narrow specific idea, provides an effective model of deliberate thinking.

The problem-solver must be comfortable with both the creative and critical thinking skills. Students must be able to use the critical thinking skills to analyze information, make decisions regarding the application of specific strategies, apply the strategies and evaluate a plan. In addition, the students will need to use the creative thinking skills to generate alternates and seek to broaden the possible ideas they would consider.

Within the heuristics of the problem solving model is a built in range of both critical and creative thinking skills. One of the inherent difficulties in the process is the assumption that the students will be able to know when and which thinking skill to transfer to the problem solving process. The wide expanse of skills needed to successfully utilize the problem solving process can be found in a myriad of thinking skills' taxonomies. (See appendix C).

Certain key skills are highlighted within the model of problem-based learning.

Inquiry skills

- observing,
- experimenting,
- criticizing,
- evaluating.

Problem Solving Skills

- sensing the problem
- finding resources to understand the problem
- defining the problem

- developing criteria
- generating alternative solutions
- evaluating the solutions based on the criteria
- creating an implementation plan

Creativity

- producing many alternatives
- producing a variety of alternatives
- producing a new or original alternative
- elaborating on an alternative

Critical Thinking Skills

- compare and contrast
- predicting
- seeking cause and effect relationships
- identifying attributes
- analysis of relationships

(Burns, 1995, 8)

A key component to any thinking skill and thinking process is the attitude of the learner. One of the greatest problems in improving problem solving is the attitude of the learner about their abilities. (Bransford, 1984) The student must be free to explore the problem. They need to remove any negative attitudes that might hinder the problem solving process. A negative attitude can impact not only the students' ability to work through the problem, but their ability to access the appropriate thinking skill. Students must be encouraged to take thinking risks and encouraged to use new thinking tools in order to fully develop their potential as problem solvers.

The following list is not unique, but a composite of thinking skill goals that could be incorporated into a problem based learning model.

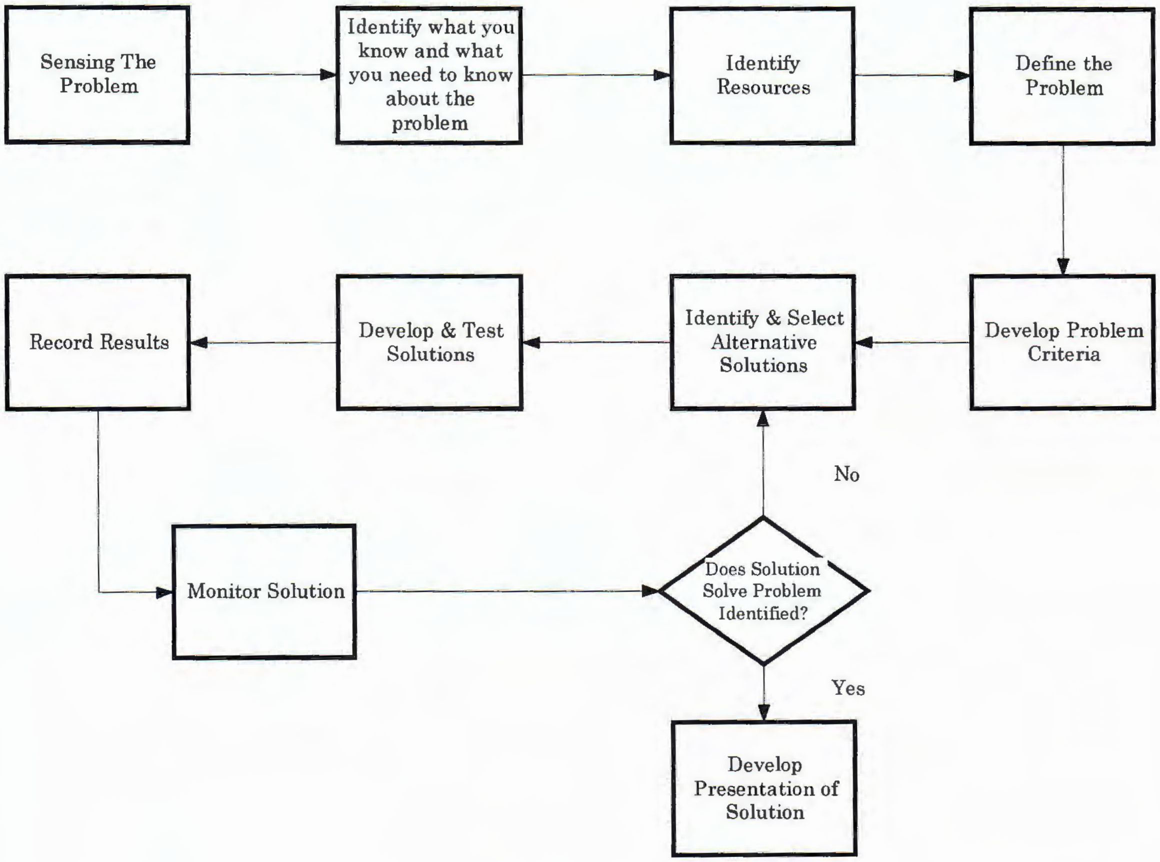
- identifying an existing problem for a given situation
- identifying different aspects of a problem

- classifying the elements of a problem
- sequencing or ordering the aspects of a problem
- recognizing divergence within a problem
- generating a variety of solutions to real world problems
- considering possible solutions to an identified problem
- testing possible solutions to an identified problem
- recognizing the possibility of more than one solution to a given problem
- judging the best solution to a problem
- implementing the solution considered to be best
- evaluating the solution implemented in regard to consequences
- drawing upon experience in a problem situation
- attempting to solve challenging problems
- conferring with others about an idea or issue
- attempting a task at which he or she has previously failed
- being open to change
- building upon an original idea with new ideas
- adding details to enhance an idea
- recognizing the relationship between problem-finding and problem-solving
- demonstrating problem-finding abilities
- posing speculative questions
- applying the positive aspects of a mistake to future situations
- developing standards to evaluate the quality of his or her won work
- becoming aware of the need to be independent in though and action (Plymouth GT curriculum, 1993, 4-8)

A Program Overview

Fig. 1. The Problem Solving Process

Using Problem Based Learning & LEGO Dacta



The flow chart demonstrates how closely this model is linked to the problem solving process. The above model differs from the standard problem solving process only with regard to the solution finding phase. In this phase the students are able to decide if the solution works based on the problem's criteria.

The following picture is part of the introductory lesson I use in my classroom. This example will be used throughout the next discussion to analysis and illustrate the proposed teaching of problem based learning with hands on manipulatives. The lesson begins by showing the students a picture of two children standing in front of a school.

Fig. 2. Introductory Lesson (LEGO TC Logo, 1989)

Using the questions from the **'Need to Know'** board, the students are asked, "What do you know by looking at the picture?" All of their ideas are listed on the board under the category **"What do you know**". The next question asked is, **"What do you need to know?".** In the case of the above picture, the students observed that they were in front of a school and wanted to know how fast the traffic was going? This question is placed in the "Need to know" category. The next question is, **"How would you find out?"** Some students decided to go to the library to explore traffic rules, while others called the Registry of Motor Vehicles, both approaches were encouraged by the teacher.

Once the students had answered all of the 'Need to Know' questions listed, they were ready to formulate their problem statement. Each group's problem statement could differ depending on how they viewed the problem. Some students focused on the issue of safety, their problem statement was "How might we create a way to get the students across the street safely?" They added two criteria, the first that the children must cross the street and the second that the solution must allow for them to cross safely. Other groups' problem statements stressed alternative ways to cross the street, their primary criteria was to keep the traffic flowing. It is important to allow for these individual differences, as long as the students are able to explain their answers based on the facts they gathered.

The next part of the flow chart is to develop the criteria for the problem solution. Using the problem statement, the students establish the criteria their solution will fulfill. Again the criteria may vary, but as the teaching coach you will want to make sure that any basic criteria established by the group is included. In the case of the picture of the children, a realistic criterion established for all groups was, 'Is the solution safe for the children?'

At this point in time all of the students' work has been done in their log books or journals. They are now ready to brainstorm alternative solutions to their identified problem. The students are asked to sketch the solution in their journal or logs. The solutions will vary just as the groups identification of the problem varied. Once the groups have chosen a solution they will begin to build the solution with the LEGO bricks. Each group will construct a model of their solution and will program that model to operate via the computer. In some cases students may not design a solution that will operate on the computer, I find that in those groups additional time is needed to become comfortable with the material before they expand onto the computer.

The LEGO material allows the students to run a trial of their solution and, as in the real world, they are able to monitor the solution for how well it works and make modifications as needed. At this point the students are actively involved with the solution finding and the teacher needs to allow for many modifications as the students work to get a successful model.

The last component is probably the most important. The students look at the solution they have built and decide if that solution does indeed solve the problem they stated. In this portion of the process, the students make the circular problem solving loop and escape from the traditional linear problem solving process. In some cases whole projects have been revamped and major modifications have been made. The students, rather than the teacher, make the determination if their project is ready to be presented to the class. The only difficulty I have found is with a group that seeks perfection in their completed project, as this may extend the amount of time needed to get the project ready for the final presentation. Setting a time limit at the beginning of the project gives the student a realistic framework in order to formulate a working timeline.

The development of the project presentation is left to the team of students. They may elaborate on their model with a visual background or add computer generated extras. The requirements for each project presentation are; 1) to prepare a brief rationale that includes the problem criteria and problem statement; 2) to demonstrate how their solution might solve the problem.

Introducing Ill-Structured Problems in the Elementary Classroom

The primary role of the teacher in problem-based learning is to present the students with an ill-structured problem and be available to ask open-ended questions throughout the process. Finding ill-structured problems that: 1) provide the student a variety of solution possibilities, 2) are of interest to the student, 3) allow for the open exploration of ideas; can be a challenge to the beginning teacher. Using resources close at hand the teacher can begin by selecting a picture that shows a conflict or possible problem situation. By eliminating any words from the picture it is open to interpretation and, therefore, will easily make an ill-structured problem the students can use. This technique makes a good first or beginning problem for students just learning the problem solving process.

One of the best sources for possible problem situations is the newspaper. Recent articles showed a problem situation with an escalator, where people were injured due to a drive belt breaking, the difficulty of homeowners with ice forming in eaves and on electric wires during the winter months, a traffic problem that MIT is trying to solve with the computer and a 1,000 ton riverboat that needs to be moved to a location that has no waterway. (See appendix D)

Once the possible problem situation is presented, students are divided into small groups and begin to discuss "What is going on in this situation?" Most of their time and focus is on problem finding and its definition. After group discussion the class is rejoined and groups share what they discovered. A diversity of ideas is welcomed as you will probably not get class consensus on problem definition.

Students begin by considering the questions from the 'Need-to-Know board : What do you observe?, What do we know about the picture?, What do we need to know?, How can we find out? In groups students work to record their ideas on the board. Information is updated, as the students discover what they need to know and new pieces of information are added. This board remains a work in process, as the students gather data about one aspect of the problem while questions will arise in other areas. I have found that the board is the central focus of the unit and that it allows for the continual cycle of problem definition, information gathering, information analysis and problem redefinition. The board serves as the students' planning and organization tool, which is especially important when they begin open-ended problem solving.

After discussion and research, which takes the form of library research, exploration of teacher gathered material, experimentation and review of expert sources, the students are able to write a problem statement. The problem statement becomes a summation of their research and their understanding of the problem. Students are advised that problem statements can be revised if they find additional information to support the revision. The problem statement was not the same in all groups. Groups might have different problem statements based on the information each gathered. Students are asked to write complete problem statements that will include the problem and the criteria they feel is important to the problem solution.

In developing problem-based lessons for the classroom the following strategies are suggested:

- Focus on developing the children's reasoning skills rather than on how correct their response might be.
- Present a problem that is based on the interest of the class, or present a choice of problems
- In order to provide background information content-based material should be introduced on a need to know basis
- Reduce direct instruction in favor of hands-on problem solving
- Provide a framework, but allow the students to plan how to handle the problem.
- Ask the students to give the reasons for their answers
- Continue to pose open-ended questions that encourages thinking

- Let the student explore and test their solutions even if you are sure the design will fail to operate.
- Make the student's feel successful, as failure is only ruling out one way that does not work
- Make available a variety of resource books to assist in their problem solving
- Encourage the students to use material other than what is provided
- Encourage diversity of design
- Encourage the sharing of ideas both between and within groups (Casey and Howson, 1993, 361-369)

Providing a Link: Massachusetts Science and Technology Framework and Problem Based Learning with LEGO Tc Logo

"A tool is but the extension of a man's hand, and a machine is but a complex tool. And he that invents a machine augments the power of man and the well-being of mankind."

Henry Ward Beecher (Flack, 1989, 63)

Strand 3 of the Massachusetts Science and Technology Curriculum Framework for students in grades five through eight informs us that students "need to pursue technological questions that emphasize creative and critical thinking, problem solving, decision making and research". (Massachusetts Dept. of Education, 1995, 86) The combination of problem based learning with the LEGO Tc Logo will help the classroom teacher meet those requirements. This model is a useful tool, as it uses the technology of the students' world, while developing the skills the students need to operate in the adult environment.

The model is a successful tool to incorporate the five "Habits of Mind" or philosophy of the Massachusetts Common Core of Learning. The following provides an overview of how the "Habits of Mind" would be incorporated in a program which uses problem based learning and LEGO TC Logo.

> 1."Curiosity in all its forms needs to be encouraged and kept alive in our students if they are to embrace science and technology." The use of the LEGO bricks foster the curiosity of the child, as they allow the child to freely explore the world by keeping the material playful and the student involved.
>
> 2. "Advances in science and technology depend on our staying open to new ideas and then examining them with a critical eye." As the student seek to define the ill-structured problem in problem based learning they must be able to remain open minded to all possibilities while seeking evidence to support their thinking.
>
> 3. "Science and technology affect human well-being and environmental quality at almost every turn." Working to define the criteria for a problem solution the safe use of the environment, materials, and tools are stressed in each problem based unit.
>
> 4. "Students must learn to respect the importance of data and testable hypotheses...." Using the criteria generated in problem based learning and the information gathered in their research the students are able to design and built a testable product using the LEGO bricks.
>
> 5. "Willingness to risk failure, to begin again, or to find a new strategy, or to fine-tune an existing one helps us to come up with better and better explanations and solutions in all areas of science and technology." One of the most important strengths of this model is the behaviors it encourages from the student. As the student is the architect of the problem and the creator of the solution their determination to persist in the problem solving process is strengthened by personal ownership. The lack of similarity to the familiar classroom tasks expands the students' willingness to take a risk in their thinking and idea generation. (Massachusetts Dept. of Education, 1995,21)

Solution Finding with LEGO TC Logo

Solution finding is the next focus of the unit, as the students list the many, varied, solutions to their defined problem. Using the sample problem one group's list of solutions included; a crosswalk, crossing bridge, traffic light, underground walkway, traffic wall, revolving chair lift, toll booth, crossing person, modified ski lift, and creating a side street around the school. Using criteria established by the students, one solution would be selected. The group's assignment was to build a model of the solution they felt best met their criteria and if it used mechanical devices program the model using the computer.

The anticipated time of the project was five forty-five minute sessions. The students were asked to keep a daily record of their ideas and the evolution of their invention in their science journals. The journal entries were an excellent way to follow the students' work in progress. The following are some examples of students' work using the sample introductory problem in Fig. 1.

Fig. 3., which follows, shows a simulated model of one group's design. Their idea was to create a conveyor belt, similar to the 'people mover' at Disney World. The journal entries of two of the students involved in the project demonstrate some of the problems they encountered in the getting their solution to work successfully.

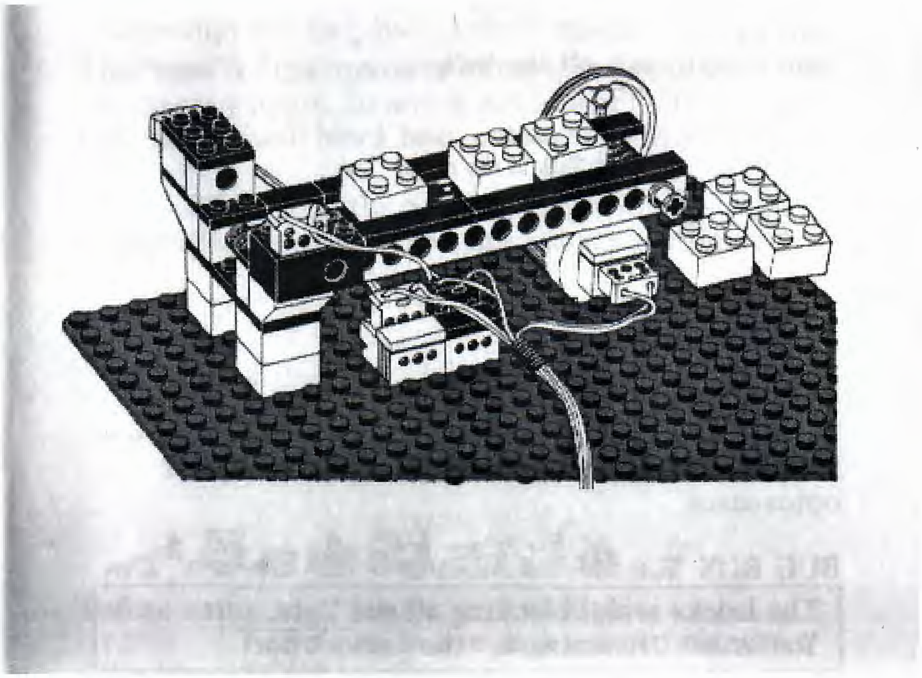


Fig. 3. The People Mover created by grade 5 students

> October 11th "We started building with only the wiring left to do. The first time we plugged it into the computer we had the wrong wire attached and it didn't work."
> October 12th "EXPLODES! We fixed our mistakes and tried again, but it exploded a second time, we redesigned and rebuilt but ran out of time."

Within the same team another student writes:

> October 11th "Stabilized the engines, but it fell apart when we tested it".
> October 12th "Worked on stronger supports for the motors, but now we are having trouble connecting the wires to the motors".
> October 13th "It finally works. We connected the Legos tighter and added more support to the Legos on top of the engine. We are having trouble programming it to run.

Another team handled the same sample problem in a different way. Their

criteria was to make the street crossing fun and they started with the idea of the students, thus they would use it rather then running into the road and it did not need to stop traffic on a busy street. One of the first problems they encountered with their design was speed, as they found that the people would fly off the GoRound into the air rather than crossing the street. Below is a model to demonstrate their design ideas and a part of the journal notes from one of the students in the group.

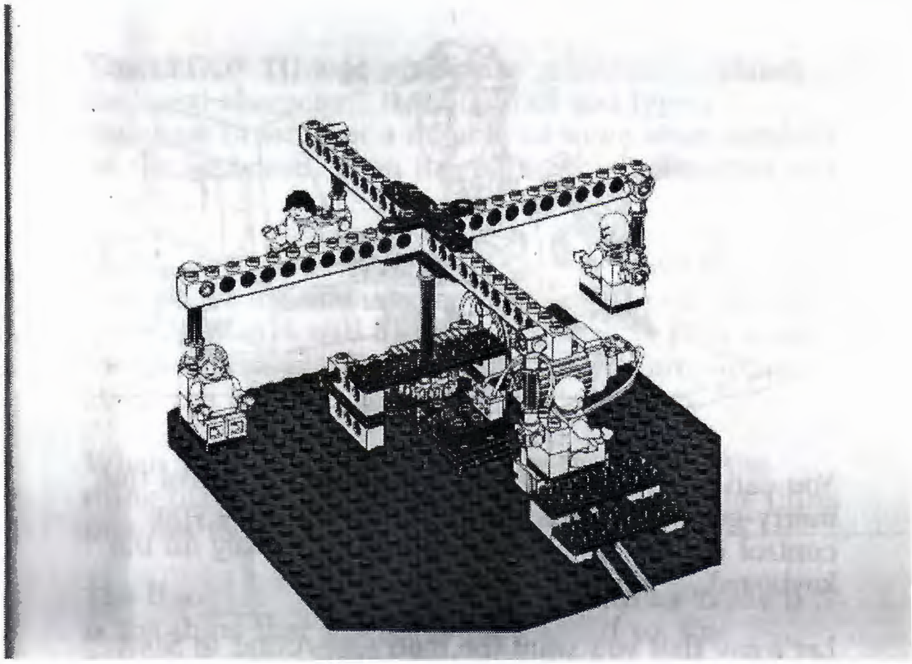


Fig. 4. The GoRound created by grade 5 students.

> October 11th "We learned how to slow down the speed by the computer program"
> October 12th " The touch sensor slowed down the ride so when the high bar got near it the ride got stuck. Other than that our ride came out just the way we wanted it to. We are going to use the GoRound because you are not in the way of the cars or trucks.
> October 13th "We put the GoRound in the back and it toppled over so we made the wires tighter" The car was flipping over and the seats were moving, so we put holders before the seat and put things at the bottom of the seats to stop them from flipping.

From the student's journal entries the trial and successes are recorded. The problem solving process moves from the realm of a paper and pencil exercise to a real world discussion with real world consequences. Flaws in their designs were spotted and redesign work was done. Failure was not considered and the students entered the exercise with enthusiasm, as problems were just situations that needed to be reexamined. At no time did the students complain about not being able to solve the problem nor did the author see a wane in their ability to cope with situations that presented new problems to solve. The students would enter the classroom each morning eager to know when they could work on their project.

The thinking skills the students were using went well beyond the problem solving process. Besides the creative thinking skills of problem solving the students had to use many of the critical thinking skills, such as, making observations, identifying attributes, compare and contrast, setting criteria, determining cause and effect. The dynamic part of the process was the ongoing use of the skills as the students worked to solve the problems. Watching the students' progress through the analytical steps of problem solving, and making real-world decisions based on real-world problems was an exciting teaching moment.

The role of the teacher throughout the lesson is varied. With some groups a quiet observer is needed while others look for a mentor. One of the strengths of using LEGO TC Logo is the opportunity it opens for the teacher.

Because each project could be different, the teacher's role needs to vary in order to meet the changing needs of the students. The less formal curriculum structure allows the teacher the flexibility of responding, "I don't know, but how might we find out?" The model asks for the teacher's role to change and for the students to look more often to themselves to accept the responsibility for their own learning.

Assessing the Student's Performance

A performance based assessment, that enables the students to demonstrate their knowledge in authentic ways is the focus of the assessment process in problem based learning. Performance assessment not only actively involves the students in the critical thinking skills and content, but provides a platform for the students to self-direct the assessment. The students' work is to plan the assessment and establish the criteria by which their work will be judged. Students can see how assessment can be linked to the learning.

The establishment of an authentic assessment is important to the success of the students' participation in a problem based unit. To teach the higher order thinking skills in a student guided format and then to test using a restrictive evaluation would not have evaluated what was valued nor taught. As the model strives for the independence of the learner, the evaluation must reflect the growth achieved and compliment the learning process. In using an objective testing tool, such as a multiple choice quiz, a mixed message would be sent to the students. The message would tell the student that although the format is open-ended the end evaluation is still based solely on the memorization of facts. By not evaluating in the same format the student would feel that classroom exploration is acceptable, but the important material is still teacher generated.

The criteria for the evaluation of the students' projects should be established at the beginning of the unit of study by the students and teacher. Students are given the assignment of presenting their work to their classmates. This presentation would be similar to an engineer, or inventor presenting their ideas to a company. The goal was to emulate the world of work as closely as possible. The students were given the freedom to design their presentation in any way they felt best reflected their team's efforts. The only requirements were the incorporation of a rationale, that explained the thinking process of their design and a demonstration of their product.

The students' presentations were as diverse as the projects they created. Groups could add to their presentation in any way they desired. Each group of students was given three to five minutes to present their finished project. These presentations demonstrate the strengths of their ideas and the group's ability to work through the problem. Each group gave both a verbal presentation and a show and tell demonstration of how their invention worked. The verbal presentation was the opportunity for the students to discuss the rationale and give the group's criteria for the development of their project.

The class chose a five point evaluation criteria to be used for both the rationale and product demonstration. The evaluation was done individually by each student and by the teacher. The five point scoring rubric is as follows: 5=exceptional; 4=very well prepared; 3=satisfactory; 2=minimal attempt; 1=non-participatory.

Group presentations were given, but individual students were evaluated on both their group work and their own individual performance. Prior to the group's presentation, each student was given the opportunity to fill out an individual evaluation sheet. This evaluation was the students' opportunity to evaluate their participation in the group's project. The group's presentation was evaluated on the following criteria: Does the solution solve the group's stated problem?, Does the idea demonstrate originality?, Was the solution realistic? Was the group able to explain the development of the idea?

The second part of the evaluation was the demonstration of the product. The same five point scoring rubric was used, but the criteria for the evaluation changed. The group evaluation was based on the following two criteria: the complexity of the product constructed and the complexity of the computer program. Some of the students were reluctant to take a risk during the design stage of the project and the evaluation was the opportunity for them to realize that there would be no penalty for reaching beyond and trying something new. Scoring was not based on how well the product looked or how well it worked, but, rather how well it matched their group's problem finding statement. The second part of the evaluation was a demonstration of the computer program they had designed. The emphasis, again, was on how far they were willing to expand their thinking. Some groups did not have successful programs, but since the criteria were not on success or failure their evaluation did not reflect this aspect. The goal was to have the students explain the reasons they felt their project might not be working and what steps they would want to take to fix the problem. By not using the success of the product as a criterion for evaluation, the students were allowed to reach beyond what might be successfully attained at this time.

Another portion of the evaluation was the student's journal entries. The journal allowed each student the opportunity to record his or her successes and failures on a daily basis. The journal emulated the role of the scientists in their recordings of the data, hypotheses, and moments of 'aha' in the creative process. The journal in problem based learning goes beyond just a scientist's notebook, as it becomes a record of the evolution of the problem. Evaluation of the journal was on-going throughout the learning experience. The daily journal entries offered the teacher an excellent opportunity to communicate with the students on a regular basis. Students were encouraged to use concept maps in their journals to help them link pieces of information they had gathered. Many students, also, used labeled drawings of various construction ideas with which they were working.

A final evaluation of the journal was done at the end of the unit. The evaluation was based on how well they kept a record of what they were doing on a daily basis. In order to allow for a broader scoring range, the scoring was changed to a ten point scale. Ten was for complete entries on a daily basis and one was given for not recording any ideas in the journal. The range between one and ten was subjective depending on the content of the individual journal. The students were the only ones to evaluate the journal entries, and an explanation needed to accompany the numeric score they gave to their work.

The last portion of the final evaluation was a written entry that evaluated the group's ability to work together and the individual student's ability to work in the group. The individual students evaluated their group work based on what they did well and what areas could be improved.

Student comments on evaluation forms gave me insights into problems they encountered. Examples of their comments are as follows:

> "I gave myself a ten on the journal writing because I wrote in it a lot. I'm glad I did because when I looked back I understood what we were doing."

> "We wrote a good program, but it was a learning process."

> "Our group worked together well and we didn't say 'No that won't work' to each other."

> "I would improve our (computer) program understanding. We had lots of trouble with that and John (one of the students from another group) was the real reason we finished. He really helped us a lot."

"I enjoyed working with Lego's. I had fun making things with them and I learned a lot too!"

This last comment became one of my favorites, because learning had occurred, but the student was seemingly unaware of the knowledge gained until reflecting upon it at the end of the unit. This student's observation maybe remarkably similar to most of our accomplishments. It seldom is possible to actually measure the depth of a learning experience until we take the time to reflect back on our performance.

In addition to the written evaluation, the students were expected to present their project to an audience. I would recommend that the audience include scientist or, parents not just an audience of their peers. By adding to the audience the students tend to use additional details in their presentations and will seek to clarify their thinking in order to make the presentation understandable to the audience. In one case, I found that I was not able to get a scientist to come in to see the students' projects, but I did find a reporter for the local newspaper, who was interested in what the students were doing and he made a wonderful audience. The students enjoyed answering his questions and the parents later enjoyed reading about it in the local newspaper.

The participation of the students in the development of the criteria and rubrics to be used was an important aspect in keeping the student's involved in the learning process. The students felt empowered and knew in advance what they needed to accomplish in order to perform at a high level. The students were then able to make informed decisions on their project, and their evaluation became not just a grade but a direction and goal. Problem based learning forces a move from paper and pencil assessment to performance accountability. It fosters hands-on student involvement and the real-life application of knowledge.

CHAPTER V

CURRICULUM EVALUATION

Evaluation of a new teaching tool needs to go beyond just the performance of the students. I have included 'A Rubrics for Assessing High Challenge Learning Environments and Opportunities'. (see appendix E) This evaluation tool was obtained from Dr. Burton Goodrich, Merrimack Education Center. (Goodrich, 1996)

The ten points of the evaluation criteria outlined in the rubrics provide the foundation for the expected outcomes of this model. Extending beyond this model, this criteria offers a broad instructional goal, which could be used in any classroom where higher order thinking skills are a priority. The suggested criteria for high challenge learning experiences are summarized in the following:

1. The degree and scope of challenge provided by the material
2. The amount of control given to the student in the learning task.
3. The opportunity for the student to work in a group.
4. The application of communication skills by the student.
5. The variety of the learning tasks.
6. The encouragement to approach the learning in different ways.
7. The instruction of problem solving skills and higher order thinking skills.
8. Tolerance of a variety of products or solutions.
9. The encouragement of the student's personal ideas
10. The motivation provided by the task beyond the value of the grade.

Each point was evaluated on a five point scale in addition to observations and comments about the success or failure of the learning experience to meet the criteria.

In evaluating the model presented in this paper, I feel its strengths are within the following areas: the students involvement in the process, the transfer of learning from research and design to implementation, the flexibility in the model's design to allow for a variety of student approaches, and the use of group interaction. The weakness of the model is the lack of variety of materials used, since all students work with LEGO bricks rather then allowing them to select other material.

Overall, I have found that the students' enthusiasm for the learning task was one of the most dynamic aspects of this model. Using this model of problem based learning and LEGO bricks the students worked well beyond my expectations as compared to using a standard instruction format. Allowing the students to direct the learning environment demonstrates how different students will grasp concepts at different rates of time. Using this framework the students can set their own instructional pace and remove the cap from the curriculum model.

CHAPTER VI

CONCLUSION

According to Barry Beyer, classrooms that welcome students' thinking provide the reinforcement and support that encourage students to risk thinking and "help students feel free to challenge, question, invent, and guess". (Beyer, 1983, 44) Beyer's statement summarizes the purpose of this proposed model. The overall goal is to provide an opportunity for students to think, not in the limited methods of recite and recall, but to think broadly and creatively. Too often students confine their thinking to a thinking box, never stretching or expanding beyond what they know, never taking a thinking risk. We, as teachers, need to help provide the classroom opportunities to open their minds, expand their abilities and awaken the natural playfulness within each student.

By introducing concrete tools, such as, LEGO bricks, we set the stage for more open behaviors and the opportunities to take thinking risks. Students view the LEGO brick as a toy, which is in sharp contrast to paper and pencil tasks. Their attitude drives their desire to create, play, explore and invent. I have found that what they accomplish by inventing with LEGO bricks can not be compared to what they will invent in a paper and pencil task. LEGO Dacta is a familiar tool that offers flexibility and adaptability to a variety of real world problems. The bricks spark the students' interest and ignite their imagination, and since they are fun to play with the students are eager to work independently of the teacher.

The problem solving process cannot be taught as a linear march from start to finish, as real-world problems do not proceed neatly through a series of steps. Real-world problems will demand the ability to reevaluate our solutions, reconsider the problem, redevelop the criteria. Students must be able to transfer the process used in the classroom to other areas of their lives and they must feel an ownership of the process. The steps of problem solving cannot be just a teaching tool, but must be assimilated into the child's basic educational framework.

Problem based learning incorporates many of the best features of the various problem solving programs currently being used. It provides the student with a forum to exercise the skills of problem solving without the strict structure used in many approaches. The student will not become entangled in the world of formulating correct word phrases to express the problem, but will become engrossed in the problem solving process. Ill-structured problems give the students a flexibility of approach and open the door to many possible problem statements. The students, rather then the teacher, become the architects in designing the problem to be solved and thus, the students rather then the teacher own the problem.

The difficulty with problem based learning using a standard research based model in the elementary grades is the resemblance it carries to a regular school task. Many elementary students, having met failure in other areas, and can easily tune out any program that looks like 'school work'. The challenge as educators is to gain their focus and attention, because without that the battle to educate becomes a war. The LEGO bricks naturally combine with the problem solving process and capture the attention of the student immediately. I have walked into a noisey classroom after recess, and by placing the LEGO kits on the table have created an attentive audience. The magic of creative play is a powerful tool.

Although LEGO bricks are considered toys, they are also a classroom tool, which can be used to educate and train the minds of the students. In one fourth grade classroom, a teacher was complaining that the students would never understand gears and gear ratios in the simple machine unit she was teaching. The teacher had spent over two weeks on the topic and many of the students had still failed the final test. The next day I did a LEGO demonstration lesson for her class, and since she had commented about their lack of understanding of gears, I used that as my lesson focus. Using the Lego gears, students spent the forty five minutes 'playing' with gears and gear ratios. All students at the end of the lesson could explain gear ratios, how gears worked and many even invented a machine using the concept of gears and gear trains. In retesting the students, the teacher found that they all passed the test on simple machines. I cannot accept credit for the success of that lesson, but in capturing their attention through play they were learning.

The use of the LEGO bricks in solution finding motivates the students to develop the behaviors that complement the problem solving process. Students are much more willing to take a thinking risk and will not demonstrate behaviors of frustration as quickly when the solution does not meet their expectations. In using the LEGO bricks, the students immediately find problems in their final solutions, which would not be as evident in a paper and pencil solutions. They are eager to reevaluate their thinking and are willing to redesign and rethink the process and make modifications to their original thinking plan. They become the real world scientists, inventors and creators with the real world problems, successes and frustrations.

In combining problem based learning with the LEGO Dacta system a marriage is made between the world of adult thinking and the world of the child. We ask the child to use the skills of the adult world as we train them for their future roles, but educationally we connect those skills with the tools of their world. The ultimate goal is to build the thinkers of tomorrow.

BIBLIOGRAPHY

Aspy, David, C.B. Aspy, P. M. Quinby. "What Doctors Can Teach Teachers about Problem-Based Learning". Educational Leadership. 50(7) (April, 1993): 22-28.

Bellanca, James, Robin Fogarty. Blueprints for Thinking in the Cooperative Classroom. Illinois: Skylight Publishing, 1991.

Beyer, Barry K. "Common Sense About Teaching Thinking Skills". Educational Leadership (November 1981): 44-49.

Black, Howard, Susan Black. Organizing Thinking, Graphic Organizers. Calif: Midwest Publications, 1990.

Boud, D. G. Feletti, ed. The Challenge of Problem-Based Learning. New York: St. Martins Press, 1991.

Bransford, J.D., R.D. Sherwood, Tom Sturdevant. In J.B. Baron, R.J. Sternberg, ed. Teaching Thinking Skills: Theory and Practice. New York: Freeman Company, 1987.

Bransford, J.R., N. Vye Sherwood, J. Rieser. "Teaching Thinking and Problem Solving". American Psychologist (1986): 1078-1088.

Bransford, J.D., B. Stein. The Ideal Problem Solver. New York: Freeman and Company, 1984.

Burns, Deborah. A Taxonomy of Thinking Skills. Storrs, Ct: University of Connecticut, 1995.

Casey, M.B., E.C. Tucker. "Problem-Centered Classroom". Phi Delta Kappan,. (Oct 1994): 139-143.

Casey, M.B., P. Howson. "Educating Preservice Teachers Based on a Problem-Centered Approach to Teaching.: Journal of Teacher Education,. (44) (1993): 361-369.

Chi, Micheline, Robert Glaser. "Problem Solving Ability". In Robert J. Sternberg, ed. Human Abilities, An Information Processing Approach. New York: Freeman Company, 1985.

Chuska, Kenneth. Gifted Learners K-12, A Practical Guide to Effective Curriculum and Teaching. Indiana: National Educational Service, 1989.

Coleman, Mary Ruth. "Problem-Based Learning". Gifted Child Today. (May/June 1995): 18-19.

Costa, Arthur L., ed. Developing Minds, A Resource Book for Teaching Thinking. Washington, D.C.: Association for Supervision and Curriculum Development. 1985.

Crabbe, A.B. The Coach's Guide to the Future Problem Solving Program. North Carolina: The Future Problem Solving Program. 1985.

Cronin, John F. "Four Misconceptions about Authentic Learning". Educational Leadership 50 (7) (April 1993): 78-80.

Davis, Gary A. Creativity is Forever. Iowa: Kendall/Hunt Publishing Co. 1992.

Flack, Jerry. Inventing, Inventions, and Inventors, A Teaching Resource Book. Colorado: Teacher Ideas Press. 1989.

Fogarty, Robin. Keep Them Thinking: A Handbook of Model Lessons. Illinois: Skylight Publishing, Inc. 1990.

Fogarty, Robin, James Bellanca. Patterns for Transfer, A Cooperative Team Approach for Critical and Creative Thinking in the Classroom. Illinois: Skylight Publishing, Inc. 1993.

Fogarty, Robin, James Belllanca. Teach Them Thinking. Illinois: Skylight Publishing, Inc. 1986.

Gallagher, S.A., W.J. Stepien, B.T. Sher, D. Workman. "Implementing Problem-Based Learning in Science Classrooms". School Science and Mathematics 95(3) (1995): 136-146.

Gallagher, S.A., H. Rosenthal, W.J. Stepien. "The Effects of Problem-Based Learning on Problem Solving". Gifted Child Quarterly 36(4) (1992): 195-200.

Goodrich, Burton. A Rubrics for Assessing High Challenge Learning Environments and Opportunities. Merrimack Education Center, 1996.

Green, Carol, John Gregory, Dale Seymour. Successful Problem Solving. Calif: Creative Publications, Inc. 1977.

Hoover, S.M. "Scientific Problem Finding in Gifted Fifth Grade Students". Roeper Review. (1991): 156-159.

______. LEGO TC Logo Teacher's Guide. Enfield, Ct.: Lego Group, 1989.

Lewis, Christine L., Sheila Buckley, Cathy Meseroll. Gemini, Gifted Education Manual for Individualizing Networks of Instruction. New York: Trillium Press, Inc. 1980.

Massachusetts Department of Education, Owning the Questions Through Science and Technology Education, draft. Malden, Ma. 1995.

Matlin, M.W. Cognition, New York: Harcourt Brace Publishers, 1993.

Mumford, M.D., M.S. Connelly, W.A. Baughman, M.A. Marks, "Creativity and Problem Solving". Roeper Review, (1993): 241-245.

Newmann, Fred M., Gary Wehlage. "Five Standard of Authentic Instruction". Educational Leadership 50 (7) (April 1993): 8-12.

Papert, Seymour. The Children's Machine, Rethinking School in the Age of the Computer. New York: Basic Books, 1993.

Papert, Seymour. Mindstorms, Children, Computers, and Powerful Ideas. New York: Basic Books Inc., Publishers, 1980.

Paul, R.W. Critical Thinking: How to Prepare Students for a Rapidly Changing World. California: California Foundations for Critical Thinking, 1993.

Paul, R., A. Biner, K. Jensen and H. Kreklau. Critical Thinking Handbook: 4th-6th Grades. A Guide for Remodeling Lesson Plans in Language Arts, Social Studies and Science. Calif: Center for Critical Thinking and Moral Critque, Sonoma State University, 1987.

______. Plymouth Curriculum Guide, Gifted and Talented Program, Grade 5. Plymouth Ma, 1989.

Rivera, Deborah B., C. Kuehne, M. Banbury. "Performance-Based Assessment". Gifted Child Today 18(5) (1995): 34-40.

Runco, M.A., J. Nemiro. "Problem Finding, Creativity and Giftedness". Roeper Review, (1993): 235-240.

Rutherford, J., G. Aikenhead. Science for All Americans: A project 2061 report on goals in science, mathematics and technology. Washington D.C.: American Association for the Advancement of Science, 1989.

Savoie, Joan, Andrew Hughes. "Problem-Based Learning As Classroom Solution". Educational Leadership 52(3): 54-57.

Schack, G.D. "Effects of a Creative Problem-Solving Curriculum on Students of Varying Ability Levels". Gifted Child Quarterly. (1993): 32-38.

Schack, Gina, "Involving Students in Authentic Research". Educational Leadership 50 (7). (April, 1993): 28-31.

Sher, B.T. Guide to Science Concepts. Williamsburg Va.: The College of William and Mary School of Education Center of Gifted Education, 1992.

Schoenfeld, A.H., "Some thoughts on problem-solving research and mathematics education. In F.K. Lester & J. Garofalo, eds. Mathematical problem solving: Issues in research. Philadelphia, Pa: The Franklin Institute, 1982.

Schwartz, S. H. "Modes of representation and problem solving: Well evolved is half solved". Journal of Experimental Psychology 91. (1971): 347-350.

Shimabukuro, Gini. "Celebrate Knowledge through Performance-Based Assessment". Think 5 (4) (April, 1995): 35-37.

Stanish, Bob, Bob Eberle. CPS for Kids, A Resource Book for Teaching Creative Problem Solving to Children. New York: D.O.K. Publishers, 1985.

Stepien, William, Shelagh Gallagher. "Problem-Based Learning: As Authentic as it Gets". Educational Leadership. 50(7): 25-28.

Sternberg, Robert J. ed. Human Abilities, An Information-Processing Approach. New York: W.H. Freeman and Company, 1980.

Sternberg, Robert J., T. Lubart. "Creating Creative Minds". Roeper Review. (1991): 608-614.

Swanson, H.L. "The Relationship Between Metacognition and Problem Solving in Gifted Children". Roeper Review, (1992): 43-47.

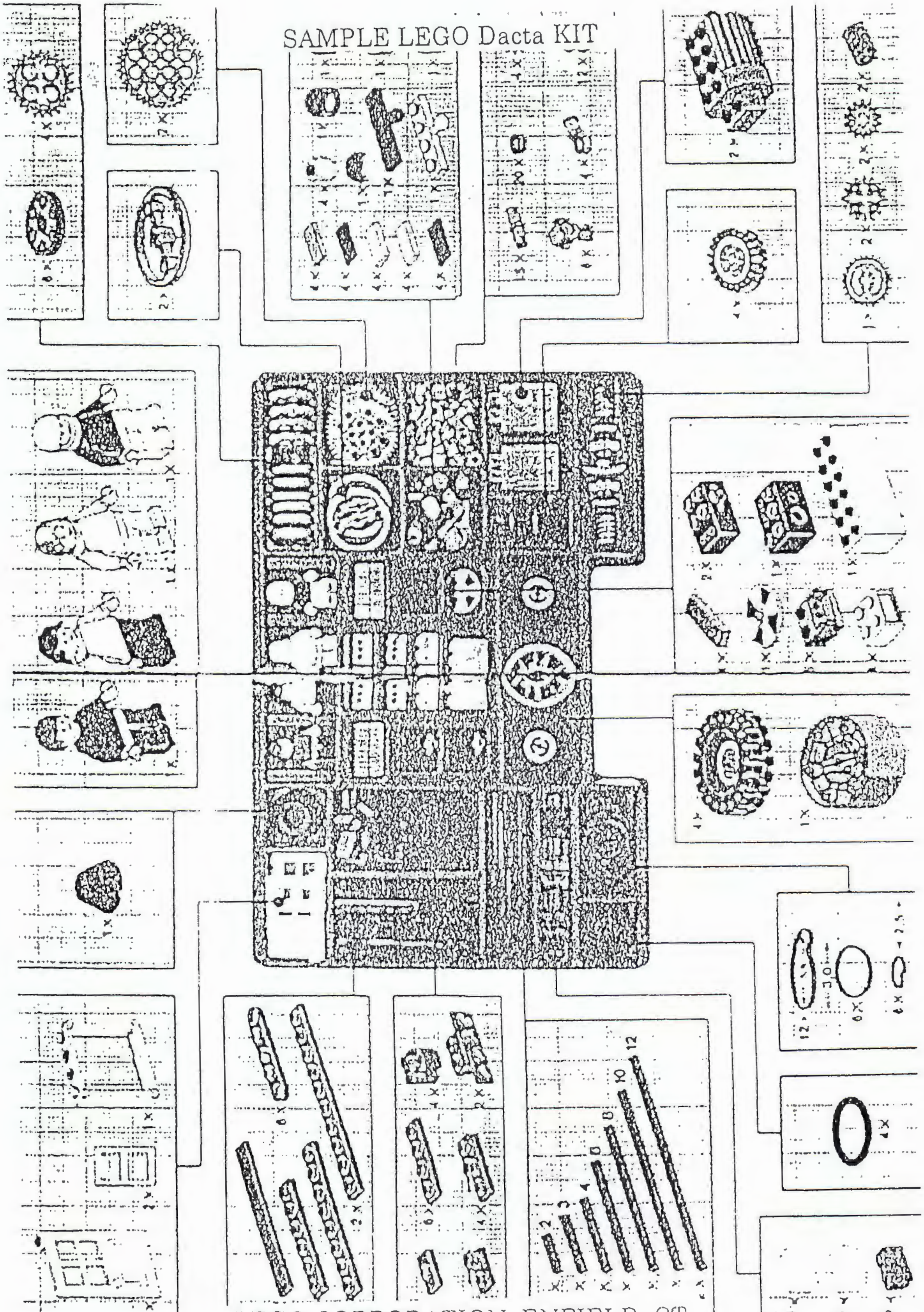
Torrance, E. Paul. The Search for Satori and Creativity. Buffalo, N.Y.: Creative Synergetics Associates, 1979.

Udall, Anne J., Joan E. Daniels. Creating the Thoughtful Classroom: Strategies to Promote Student Thinking. Tucson: Zephyr Press, 1991.

APPENDIX A

SAMPLE LEGO KIT

SAMPLE LEGO Dacta KIT



LEGO CORPORATION, ENFIELD, CT.

APPENDIX B

QUESTIONING STRATEGIES

Types of Questions Used in the Socratic Method

Questions of Clarification

What do you mean by ____________________?

What is your main point? Could you give me an example? Could you explain that further?

Would you say more about that? What do you think is the main issue here?

Let me see if I understand you, do you mean ________________ or ________________?

Is your basic point ____________ or __________?

What do you think John meant by his remark?

Jane, would you summarize in your own words what Richard has said? Richard, is that what you meant?

How does ___________ relate to ___________?

Could you put that another way?

Questions that Probe Assumptions

You seem to be assuming __________________. Do I understand you correctly?

All of your reasoning is dependent on the idea that ____________________.

Why have you based your reasoning on __________ rather than ____________________________?

You seem to be assuming __________________.

How would you justify taking this for granted? Is it always the case?

What is Karen assuming? What could we assume instead?

Questions that Probe Reasons and Evidence

How do you know? Why did you say that?

What would be an example? How could we go about finding out whether that is true?

What other information do we need to know?

By what reasoning did you come to that conclusion?

Could you explain your reasons to us?

But is that good evidence to believe?

What are your reasons for saying that? Why do you think that is true?

Do you have any evidence for that? Are those reasons adequate? Is there reason to doubt that evidence?

Who is in a position to know if that is the case? What difference does that make? What would convince you?

Can someone else give evidence to support that response? How does that apply to this case?

Questions about Viewpoints or Perspectives

You seem to be approaching this issue from ________ ________________ perspective.

Why have you chosen this rather than ____________ ____________________ perspective?

How would other groups/types of people respond? Why? What would influence them?

How could you answer the objection that __________ ______________________ would make?

Can/did anyone see this another way?

What would someone who disagrees say?

What is an alternative?

How are Ken's and Roxanne's ideas alike? Different?

Questions that Probe Implications and Consequences

What are you implying by that?

When you say _________ are you implying _______?

But if that happened, what else would also happen as a result?

Why? What effect would that have?

Would that necessarily happen or only probably happen? What is an alternative?

If this and this are the case, then what else must also be true?

Questions about the Question

I'm not sure I understand how you are interpreting the main question at issue.

How can we find out? How could someone settle this question?

To answer this question, what questions would we have to answer first?

Is the question clear? Do we understand it?

Is this the same issue as ____________________?

Can we break this question down at all?

Do we all agree that this is the question?

Would ______________ put the question differently?

How would __________________ put the question?

Why is this question important? Is this question easy or hard to answer? Why?

Does this question ask us to evaluate something?

What does this question assume?

SOURCE:

This is reprinted with permission from R. Paul, A. J. A. Binker, K. Jensen, and H. Kreklau, *Critical Thinking Handbook: 4th-6th Grades. A Guide for Remodeling Lesson Plans in Language Arts, Social Studies, and Science* (Rohnert Park, Calif.: Center for Critical Thinking and Moral Critique, Sonoma State University, 1987.)

APPENDIX C

MATRIX OF THINKING SKILLS

MATRIX OF THINKING SKILLS

Complex-Level Thinking Skills*

Complex-Level Thinking: A type of cognition that requires basic thinking and is characterized by multiple possible answers, judgment on the part of the person participating, and the imposition of meaning on a situation. Types of complex thinking include critical thinking, creative thinking, and problem solving.

CRITICAL THINKING

A type of complex-level thinking characterized by the careful analysis of arguments, use of objective criteria, and evaluation of data.

1. Inductive thinking skills
   - Determining cause and effect
   - Analyzing open-ended problems
   - Reasoning by analogy
   - Making inferences
   - Determining relevant information
   - Recognizing relationships
   - Solving insight problems

2. Deductive thinking skills
   - Using logic
   - Spotting contradictory statements
   - Analyzing syllogisms
   - Solving spatial problems

3. Evaluative thinking skills
   - Distinguishing between facts and opinions
   - Judging credibility of a source
   - Observing and judging observation reports
   - Identifying central issues and problems
   - Recognizing underlying assumptions
   - Detecting bias, stereotypes, cliches
   - Recognizing loaded language
   - Evaluating hypotheses
   - Classifying data
   - Predicting consequences
   - Demonstrating sequential synthesis of information
   - Planning alternative strategies
   - Recognizing inconsistencies in information
   - Identifying stated and unstated reasons
   - Comparing similarities and differences
   - Evaluating arguments

CREATIVE THINKING

A type of complex-level thinking that produces new and original ideas.

- Listing attributes of objects/situations
- Generating multiple ideas (fluency)
- Generating different ideas (flexibility)
- Generating unique ideas (originality)
- Generating detailed ideas (elaboration)
- Synthesizing information

PROBLEM SOLVING

A type of complex-level thinking that uses a number of sequential skills to solve a problem.

- Identifying general problem
- Clarifying problem
- Formulating hypothesis
- Formulating appropriate questions
- Generating related ideas
- Formulating alternative solutions
- Choosing best solution
- Applying the solution
- Monitoring acceptance of the solution
- Drawing conclusions

SOURCE:

*Adapted from Gubbin's Matrix of Thinking Skills. Gubbin's Matrix compiles and distills ideas from Bloom, Bransford, Bruner, Carpenter, Dewey, Ennis, Feuerstein, Jones, Kurfman, Kurfman and Solomon, Lipman, Orlandi, Parnes, Paul, Perkins, Renzulli, Sternberg, Suchman, Taba, Torrence, Upton, The Ross Test, the Whimbey Analytical Skills Test, The Cornell Critical Thinking Test, the Cognitive Abilities Test, the Watson-Glasser Critical Thinking Appraisal, the New Jersey Test of Reasoning Skills, and the SEA Test.

APPENDIX D

SAMPLE PROBLEM SITUATIONS

Several methods may be used to keep ice from forming at eaves

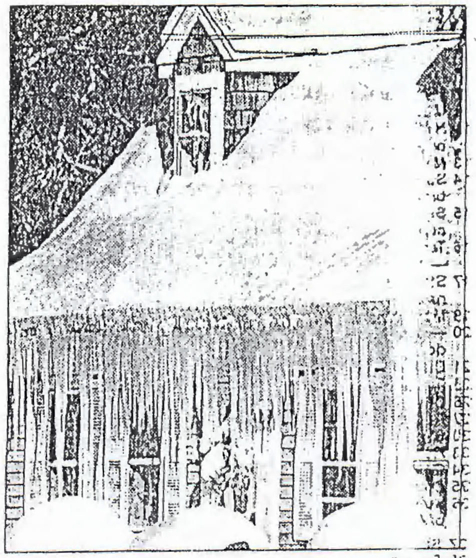
From Ottaway News Service

During this cold, snowy winter, icicles have been a particular problem: Giant stalactites of ice hanging from snow-laden roofs, waiting to impale people or cars below. Icicles form when it's sunny but cold enough to freeze the water as it drips from eaves and ice-filled gutters.

To prevent them, experts recommend removing as much snow as possible from the roof. Hire a building professional to do the work or use a long-handled roof rake, sold at hardware stores for about $45.

When knocking down icicles, take care not to damage the gutters or eaves. Make sure no children are playing in the area. Direct icicles away from the house and use a tarpaulin to cover windows that may break in the process.

Whe the roof is ice-free, electric gutter cables can be installedto melt snow and keep ice from forming along the eaves. They plug into regular electrical outlets and feature timed, automatic shutoffs. Sold at hardware stores, they start at $35 for a 30-foot cable.



File photo

Electric gutter cables can be installed to melt snow and keep ice from forming along the eaves.

T escalator accident blamed on drive belt

Patriot Ledger staff

BOSTON — An escalator mishap at the MBTA Back Bay station that sent 14 commuters to the hospital yesterday was apparently caused by a drive belt that snapped.

Although that escalator had no history of similar problems, in recent days the T received a complaint that something was wrong.

"We had a comment that the escalator was moving at a slow pace," MBTA spokeswoman Amy MacNeil said.

To deal with that problem, the T had called in its escalator maintenance contractor, the Milar Elevator Service Co.

Milar inspected the escalator the day before the mishap and deemed it in working order, MacNeil said.

"They didn't find any problems," she said.

But just before 8 a.m. yesterday, as it carried a full load of people, a drive belt snapped, MacNeil said.

The escalator stairs shook and started moving backward, tossing its passengers into one another and against the sides of the escalator.

Fourteen adults were taken by ambulance to Boston City Hospital, where they were treated for minor injuries.

The escalator was taken out of service and will remain out of use until the state decides it is safe, MacNeil said.

It is on the Track 2 side of the commuter rail area of the station, near the ticket office.

The Back Bay station is both an Orange Line subway stop on the MBTA and a commuter rail terminal for trains from Canton, Stoughton and Sharon.

The state Department of Public Safety, which does annual inspections of escalators and elevators, last checked the Back Bay station escalator in September.

SOURCE: Boston Globe, 1996

SAMPLE PROBLEM SITUATION

Science Musings

CHET RAYMO

Drivers take byte out of computer

The newspaper recently ran a story about a computer traffic model developed by MIT traffic researchers that is being used by the builders of the Central Artery/Third Tunnel project to find trouble spots that may need redesigning.

When the model is running, hundreds of blips of light move about the screen, simulating traffic on the yet-to-be-completed project.

The MIT model is the most sophisticated traffic simulation yet designed, and takes into account such real driver behaviors as running yellow lights, tailgating, and passing in the breakdown lane.

This is not the first attempt to model Boston traffic on a computer. An earlier effort by researchers at Washington Institute of Technology was abandoned when their computer unexpectedly blew up.

To find out what happened, I visited the defunct project's ex-coordinator, Crash Gordon, at WIT.

"Tell me about the WIT computer traffic model," I said.

"At the time, it was the best in the country," responded Gordon. "Funded by of $50 million grant from the Department of Transportation. Used one of the biggest and fastest computers money can buy. Our model took into account many nuances of driver behavior, good and bad."

"Was it successful?"

"The model worked beautifully in Chicago, Tulsa, Los Angeles. The engineers were ecstatic, highly satisfied. Then we got the contract to do Boston. . ."

> "The model worked in Chicago, Tulsa, Los Angeles. Then we got the contract to do Boston."

Gordon gazed off into space, in an unfocused sort of way.

I waited, then prodded. "And. . .?"

He continued: "First we sent observers to Boston to survey traffic patterns. We took psychological profiles of hundreds of typical drivers. We created a mathematical model of the Boston road system and the proposed Central Artery/Third Tunnel. Then we started up the machine."

"At first, things went well. Traffic moved smoothly along Storrow Drive. The Tobin Bridge handled the required volume. Oh, the computer gave us an occasional backup at the airport side of the old tunnels, but nothing we couldn't fix by tweaking the project's design."

Gordon's eyes misted. "Then we started plugging in peculiarly Bostonian features. . ."

"Such as?" I asked.

"Such as rotaries. We didn't have much experience with rotaries. The computer kept getting hung up. Blips on the screen went round and round, endlessly, as if they couldn't get on or off. We had to keep when we added emergency vehicles to the model, which we represented on the screen as flashing orange blips. As an orange blip moved at an accelerated pace through four lanes of traffic, other blips darted in behind, as if they were trying to get the jump on their fellow drivers. I had never seen anything like it before. At first, we thought something was wrong with the computer."

"Slowly we realized our queuing models were faulty. Queuing in the Boston profile was non-existent. The blips on the screen would use any stratagem to get to the front of the pack: emergency vehicles, breakdown lanes, even sidewalks, for God's sake."

"Same for merging lanes. In other parts of the country, drivers in adjaecent merging lanes take turns. With the Boston data, blips jammed together bumper to bumper, blocking any blip that wanted to merge.

"Intersections! Blips packed into intersections as traffic lights changed to yellow and red, even if egress was blocked, thereby bringing traffic in all directions to a standstill. We kept getting code-error messages on the screen, but it wasn't the code. . ."

Gordon lit up a cigarette. I noticed his hand was shaking.

"Then one of our guys had the idea of adding pedestrians to the model. Big mistake," he said wearily.

"How's that?" I asked.

"Well, the model included crosswalks. But the pedestrian blips crossed thoroughfares at random ingress points. We simply didn't have the memory capacity in our machine to model random ingress."

"We upgraded memory capacity by 100 gigabytes, then 500. But as we added more features to the model – cyclists, for example – even this wasn't enough. We could find no algorithm that would concisely specify driver, cyclist, or pedestrian response. It was as if there were no rules."

He paused. "It was when we added yield signs that the computer blew. Burned out the main processor chips."

"And that's when the contract was canceled?" I asked.

"Right," said Gordon. "But to tell you the truth, none of us at WIT were sorry. We repaired the machine. We now have a contract with Atlanta. Everything is going swimmingly."

"Well, good luck," I said.

"You too," said Gordon. "And give my best to the guys at MIT."

APPENDIX E

A RUBRIC FOR ASSESSING HIGH CHALLENGE LEARNING ENVIRONMENTS AND OPPORTUNITIES

A RUBRIC FOR ASSESSING
HIGH CHALLENGE
LEARNING ENVIRONMENTS AND OPPORTU

Suggested Criteria for High Challenge Learning Experiences	Observations and Comments about the degree to which the Desired Characteristic is Present in the Learning Experience	Rating: 5 = Always 4 = Most of the time 3 = Some of the time 2 = Occassionally 1 = Never
1. To what degree is the student involved in tasks that are broad in scope (not divided into fragmented tasks), and provide a challenge (intellectually demanding and not easily accomplished)?		
2. To what degree does the student have control over the work process (not directed by a dominating hierarchical authority)? Is the teacher or instructional delivery system a "coach" or resource, not a "supervisor"?		
3. To what degree is the student given opportunity to work collaboratively and cooperatively?		
4. To what degree is the student given opportunity to practice or apply communication skills during the learning task?		

SOURCE: Dr. Burton Goodrich, Merrimack Education

Suggested Criteria for Selecting or Creating Inquiry-based Learning Experiences	Observations and Comments about the degree to which the Desired Characteristic is Present in the Learning Experience	Rating: 5 = Always 4 = Most of the time 3 = Some of the time 2 = Occassionally 1 = Never
6. To what degree is the student encouraged to try different ways of coping with or addressing the learning task?		
7. To what degree does the learning task explicitly teach problem solving and higher-order thinking skills or provide opportunity for the student to apply and reflect on these skills?		
8. To what degree is there variety in what is considered an acceptable approach, product, or solution to the learning task (responses are not standardized)?		
9. To what degree are the student's personal ideas and contribution to the task or product encouraged and valued?		