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Basic Robotics Curriculum: An Introductory Unit for Junior High School Students

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Basic Robotics Curriculum:
An Introductory Unit
for Junior High School Students

by
Patricia Sims

A thesis submitted to the Division of Curriculum and Instruction
in partial fulfillment of the requirements
for the degree of Master of Education

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ABSTRACT

The purpose of this project was to research and develop a robotics curriculum appropriate to junior high school students. Specifically, this project developed a two-week, ten-hour robotic curriculum to introduce eighth-grade students to basic robotic concepts.

After a careful examination of the related literature and after an evaluation of current trends in robotic education, objectives were developed. The objectives integrated content from industrial arts, science, college-level courses on robotics, and very basic concepts used in elementary schools as an introduction to robotics. Lessons were developed which used a multisensory approach and activities emphasized hands on experiences for students.

Conclusions which were drawn after a review of related literature, development of the curriculum, and pilot testing are included along with recommendations for possible improvement and expansion of this project. The importance of keeping pace with developing technologies is stressed throughout the curriculum which was developed.

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Table of Contents

	Page
Abstract	
Acknowledgements	
CHAPTER I - Introduction -----	1
Problem Statement -----	1
Definition of Terms -----	6
CHAPTER II - Review of Related Literature -----	8
Background Information -----	8
Educational Uses -----	16
Classification of Robots -----	17
1. Hero -----	25
2. Topo -----	27
3. RB5X -----	29
4. Tasman Turtle -----	30
CHAPTER III - Procedure -----	32
CHAPTER IV - Curriculum -----	35
CHAPTER V - Suggestions for Teaching This Curriculum ---	61
CHAPTER VI - Conclusions and Recommendations -----	63
References -----	67

CHAPTER I

Introduction

Problem Statement

Science has given birth to a new technology called "robotics." Robotics is generally defined as the study of the construction, maintenance, and behavior of robots. Robots are mechanisms or electronic devices that perform functions ordinarily ascribed to human actions through automatic controls. A robot can be anything from a child's toy to a very complex "synthetic" person.

Many educators are currently arguing that the general population needs to become educated in this new field of robotics. Even though robotics is still in its infancy, it is expected to play a significant role in everyday life in the near future (Maus, 1986). Robots will be taking over many of the mundane jobs that currently require people to perform them, such as routine domestic chores, auto maintenance, and most assembly-line work. Other tasks will be done by self-programming robots that can appraise situations and use logic to adapt behavior for each set of circumstances.

Since most people will be dealing with robots in one form or another during their lifetimes, it is important to help everyone understand robots. Education should help prepare the general population to fit into society. Since

society changes with the technology it has, it is important that education keep pace with new technology and adapt curriculum to educate the population to each new development. The time to develop, test, and implement curriculum on robots is now and not in some "unknown" future. The unknown future may be less than five years from now.

Moreover, since robotics as a technology is in its infancy, it is important that curriculum for the already existing knowledge base be developed; therefore, as more advances are made, the educational system can incorporate them and not lag behind. If the educational systems were to start including robotics in the curriculum now, it might be possible to add new innovations more easily as they are developed.

Children of the 1980s have grown up surrounded by robots. The popularity of transformers and other artificial robots, as well as cartoons and movies that feature robots, has removed any hesitation students might have previously had regarding robots. Since children are already at ease around robots, it should be easy to educate them to the concepts of robotic technology. Adults, as is generally the case, may be more hesitant to change, due partly to their unfamiliarity with the subject. But, with the proper approach, everyone can be educated in robotics.

A robot in reality relies on central computers of many different kinds to control all its actions. This means robotics is linked directly to computer technology. As computers become more advanced and inexpensive, the more complex and cheaper robots will become. With the price of computers decreasing as rapidly as it has been, robots will quickly become affordable to most people.

A good example of what can happen if education does not keep pace with developing technologies can be seen in the computer field. Education lagged behind in implementing the computer curriculum. It has only been in the last three years that the State of Florida has included behavioral objectives for computer education in its curriculum. It took so long for curriculum to be developed within the computer field that by the time it did occur and appropriate instruction had been implemented, both the software and the hardware included tended to be outdated and often obsolete.

It has only been in the last ten years that computers have become an everyday aspect of most people's lives. Almost everyone uses a computer in one form or another. Most banks have automatic tellers; grocery stores, department stores, and businesses use computers to record transactions and to inventory accounts. Ten years ago everyday use of computers was incomprehensible to most people; now they touch most people's everyday lives.

Education should have helped people make the transition into a computerized society. Instead, it seems that what it has done is teach outdated concepts.

In order to eliminate the reoccurrence of this problem, the educational system needs to start preparing the general public to make the transition into a robotic affluent society. In particular, school age children should be aware of what constitutes a true robot and understand how it works in order to adapt more easily into a robot affluent society.

Moreover, since many students start making lifetime career choices at an early age, it is important that they be introduced to robotics early enough to allow it to be considered as a career choice. Introducing such a curriculum at the junior high level would thus make it possible for students to attain this exposure before major career decisions need to be made.

The students taking a course on robotics should also have some limited computer background before studying robotics. If the students are already familiar with basic computer concepts and are aware of the purpose of computer languages, it would allow a more in-depth study of robotics to take place in a shorter time. Since every eighth-grade student in the state of Florida must complete a two-week course in computers, it would seem ideal to design a robotics course to follow immediately after the computer

class. This would allow students to build upon their newly obtained knowledge.

Therefore, the purpose of this project is to develop a robotics curriculum for eighth-grade Florida students that would correlate with the computer curriculum. Specifically, this project will develop a two-week, ten-hour robotics curriculum to introduce eighth-grade students in Duval County, Florida, to basic robotic concepts which will follow the county-wide two-week computer education curriculum.

Definition of Terms

Automatons Robots: A classification of mechanical devices that perform a predefined program. They are not true robots.

Autonomous Robots: A classification of robots that contain a microcomputer with "analog-to-digital" interface and sensors. They are true robots.

Hardware: Major items of computer equipment or their components.

Homebrew Robots: A classification of robots which are made by individuals, groups, or clubs.

Industrial Robots: A classification of robots that perform a wide range of jobs that were previously done by humans. They are true robots.

Mechanical Arm: A mechanical device that functions similar to a human arm in motion and action.

Phonemes: The individual sounds that language is broken into by robots to form spoken words.

Robot: A reprogrammable device designed to both manipulate and transport parts, tools, or specialized manufacturing implements through variable programmed motions for the performance of specified tasks.

Robotics: The term used to describe the study of robots.

Sensor: A device that provides information about the state of the robot and its environment.

Software: The program or programs controlling the operation of a computer or microprocess.

Toy Robots: A classification of mechanical devices that are sold as robot toys. Some are true robots, some are not.

Ultrasonic Sensors: Sensors that transmit high frequency signals that operate like crude sonar devices.

Umbilical Robots: A classification of robots that are usually interfaced through long cables to a microcomputer. They are true robots.

CHAPTER II

Review of Related Literature

Background Information

The term "robotics" was coined by a science fiction writer, Isaac Asimov, in 1940 (Reichardt, 1978). Because science fiction is the origin of the term robotics, the scientific community was slow to accept it; now the term is well accepted. It is even an identifier in the ERIC system, which is the Education Resources Information Center.

The term robot was first used by Capek in 1917 in his play "Opilec." The word "robot" comes from the Czech "robota" which means obligatory work or servitude. It stems from the feudal period when peasants owed labor to their masters for food and shelter. Capek's play has given an overall name to an entire range of objects: mechanical and electronic humanoids, androids, and manikins whose original purpose is to serve people but whose ultimate purpose might be something quite different (Reichardt, 1978).

Todd (1986) has developed a list of characteristics that seem essential for a true robot; these characteristics can be described in several ways. A robot should be manufactured rather than produced through biology; muscles and other structures may be produced through artificial biochemical processes. A robot must either move or be able to move physical objects; this eliminates simulations and

control systems from being robots. A robot must either have a power or force source or it must amplify power; as an example, some teleoperators are considered true robots, but teleoperated arms which merely reproduce an operator's hand or arm movements are not. The next characteristic of a robot is that it must be capable of continual functioning without external intervention; it must be able to continue working without constant directions from outside. Lastly, a robot must be equipped with sensors and be able to modify its behavior based on environmental changes detected by its sensors. Therefore, robots generally need to be able to perform a variety of specified tasks involving perception and decision-making with human-like ability.

The official definition of robots issued by the National Robotics Association and found in most books on robotics is as follows: "A robot is a reprogrammable and multifunctional manipulator, devised for the transport of materials, parts, tools, or specialized systems, with varied and programmed movements, with the aim of carrying out varied tasks" (Todd, 1986; Lane, 1986; Maus, 1986). It should be understood that a robot is a "programmable" multifunctional manipulator, and not every manipulator can be considered a robot. This definition thus eliminates many false so-called robots such as golems, teraphims, homunculus, and automatons. Robots are, in fact, a peripheral extension

of computers in which the robots of all types receive their instructions from a central computer. This means that the complexity of the computer determines the efficiency of the robot.

Robot research began in the early 1950s with the developmental work of Deval. He is commonly considered the founder of robotics because of his programmable manipulator. Deval's robot, patented in 1961, was basically a programmable machine designed for pick-and-place tasks that had originally been done by people. The use of early robots was centered around designing ones that could operate in environments that humans could not or did not wish to withstand. The essence of robotics technology, according to Maus (1986), is to develop machines that are capable of performing a given task better, faster, safer, and cheaper than a human being can.

In 1956, Deval and Engelberger founded Unimation, Incorporated, the first robot manufacturing firm. They wanted to design programmable robots to do tasks that were too dangerous or tedious for people to do. They conducted the first robotics applications study in automobile assembly plants and other manufacturing operations to get information on what kind of robots were needed. They decided through this study that robots could in fact take over the most dangerous and repetitive jobs in the manufacturing environment.

In the 1950s Unimation produced a successful working model of a robot for under \$10,000. Seventy-five percent of the cost was for electronics and 25 percent was for mechanical parts. Now the cost ratio is reversed. By 1961 the prototype was fully tested and placed in a real manufacturing environment. It loaded and unloaded a die-cast machine in a fabrication plant at General Motors. The robot is now retired in the Smithsonian Institution in Washington, D.C.

Between 1961 and 1975 robotics expanded, and many new robots were developed and put into American factories. Some of these early robots are still hard at work today; some have logged well over 100,000 hours of labor, which is equivalent to over 50 years of work by an average laborer.

In 1975 the Robot Institute of America was founded. This group provided a data base for robot developers, users, and manufacturers so that they could share ideals and pitfalls.

In the late 1970s there was a turning point in robotic development. The microchip made computers faster, cheaper, and more powerful. Robotics directly reaped the benefits of this new breakthrough in technology. Prior to this new development, robots had been limited by the speed at which computers could process information and by their inadequate memory space to store programs. The microchip allowed

computers to process information quickly, provided needed storage space in memory, and, best of all, made computers affordable (Maus, 1986).

Since the cost of computers has dropped so dramatically, the computer has become part of everyday life, and people's attitudes have begun to change about automated equipment. Robots have left the science fiction world and have entered the real world (Maus, 1986).

Maus (1986) and Meinert (1985) describe present and future development in robotics. Currently, Japan and the United States share 69 percent of the total 100,000 robots working in the world. However, only 15,000 robots are in American factories now. There are still 19 million factory workers doing boring and dangerous manufacturing tasks that robots will eventually be doing. Robot manufacturers predict that by 1990 the United States will be producing over 20,000 robots per year, up from 450 in 1980. General Motors expects to increase its number of plant robots from 300 in 1980 to over 10,000 in 1990. By 1990, there could be a total of over 80,000 robots working in industry; at that time the implementation of robots is expected to increase 35 percent each year throughout this decade.

Maus and Meinert further state that future robots will be able to perform a much wider variety of tasks; they will be more versatile and able to handle much more complex

assignments than today. Tactile sensing will be greatly improved which will allow robots to become more sensitive to their environment and more able to respond to it. Movement will become freer, and lighter weight materials will allow faster movement.

Today, some sophisticated robots can work even better than people because they perform the same tasks repeatedly with only a small deviation in accuracy, according to Reichardt (1978). He further states that since the earliest days of robotics one of the main attractions of robots' usage has been the ability of robots to function in environments incompatible to people. There are currently robots functioning in many of these hazardous environments. They work around radiation in the nuclear and military fields. They work around extremes in temperature in foundries; they use abrasive particles to grind; they work around sparks and molten metals, corrosive chemicals, steam, paint spraying, and electrical noise. In all of those situations, they save people from health-related problems.

Many authors indicate that the next step in the continuing industrial revolution is robotics. Albus (1984) further states that the next industrial revolution will substitute computer power for brain power in controlling machines and industrial processes and will be based on robot labor. He calls it the "robot revolution." He argues that

this revolution will free the human race from regimentation and mechanization that, he states, are currently imposed by the necessity of manual labor and human decision-making in factories and offices. He also states that the robot revolution has the potential of bringing a golden age to mankind by providing material wealth, clean energy, and personal freedom.

According to Maus (1986), there are four generations of robots. In the general public educational system the study of robotics will primarily be limited to the fourth generation of robots. However, in order to understand why, it is important to outline all the generations. The four generations are described here according to the way Maus conceived them.

The first generation of robots included primitive operating machines that had very limited movements. They were used exclusively for pick-and-place tasks in engineering industries. Even so, some of those first robots are still being used today.

The second generation of robots was programmed by using a button box. The task sequence the robot was to perform was recorded on magnetic tape. When the magnetic tape was played back through use of the button box, the robot "learned" the desired task and would repeat the same task each time the tape was played. Many of these second

generation robots are used in the automobile industry for spot welding and spray painting.

The third generation of robots includes, for the first time, computer-programmable robots. They are hooked directly to the computer through a communication link and receive all their directions from the computer. They became commercially available in 1981. The sensing capabilities of the third generation of robots are very limited. They were programmed with "impenetrable coordinate systems" and not in terms of objects. It can be assumed that they see in two dimensions instead of three dimensions; thus, there is no ability to see depth.

The fourth generation of robots is currently being developed. They will feature arms, legs, jigs, and feelers that work together in synchronized movements. Their tactile senses will be vastly improved to allow the robot a sensitive touch. Another improvement will be artificial intelligence. It will allow robots the freedom to make decisions and solve many of the current problems people have to solve for robots. Artificial intelligence will allow robots to be self-programming, decision-making, problem-solving machines.

Educational Uses

Reichardt (1978) feels there are basically only two major forms of learning gained from robots. One is using the robot as a teacher, or an interactive computerized teaching device, to ask and answer questions. The other use is for the robot to simulate a person or process, which allows students to gain practical experience in physical manipulations and in the consequences.

Reichardt also thinks that a team of robots working in a group of schools with a central computing system would provide the most democratic educational tool available today because the robots could provide individualized instruction to every student. This system could alleviate many of the difficulties teachers face in coping with a large heterogeneous class that demands constant supervision. Reichardt also states that after the initial expenditure, robots will be less expensive in helping students achieve a competency level than the conventional methods now employed. He feels that the use of robots could be the only way to achieve a truly democratic education that allows students to be taught at an appropriate level for as long as necessary to achieve a desired level of competence.

The most current account of robotic education was done by David Hull. Hull's report in 1984 presented the results of research conducted to determine the current state of the

art of robotics and automated systems technician training in the United States. Public and private institutions providing technician training were the information sources through a project survey. The results indicated that: 56 institutions provided robotic/automated system technician training programs; 114 schools offered robotics courses as electives; 159 instructors taught robotics, and 5,472 students were studying to become robotic technicians in the two-year associate degree and certificate programs; 33 texts were being used in training robotics technicians, and 27 other competency-based modular texts were available. There was a state-by-state listing that identified schools offering robotic training. Appendixes included raw survey data, a bibliography, and a chart of colleges and universities offering robotic training.

Classification of Robots

Since the field of robotics is so diverse it is necessary to classify robots by types, based on similarities. This will allow a better perspective of robots and their educational uses.

The classification scheme developed by Van Horn (1986) separates robots into eight types. This scheme provides a category for virtually all kinds of mechanical devices that can remotely be considered robots. This classification includes automatons, industrial robots, toy robots,

umbilical robots, robot arms, study robots, autonomous robots, and homebrewed robots.

The automatons are remote controlled mechanical devices that perform a predefined program. They are highly visible and can be seen at Disney Center and places like Showbiz Pizza Place. Although they look very sophisticated, they are, in fact, very similar to a synchronized slide projector, which advances to inaudible tones. Automatons are not considered true robots.

The next classification in Van Horn's scheme is the industrial robot. This is a broad category of machines that perform a large range of diverse jobs previously done by paid employees. Industrial robots are often taught their movements by master craftsmen. Some of the jobs done by these robots are spray painting, welding, picking-sorting-placing parts, inspection, assembly, and industrial security.

Currently, the most visible of this class is the factory or industrial robot (Meinert, 1985). This robot is stationary and consists of one arm. Industrial arts and vocational educational classes have developed most of their limited robotics curriculum on only industrial robots, and it is often too technical for most people. Since the purpose of this project is to enlighten all students, the study of industrial robots for technical training will only be briefly discussed.

There is now a wide choice of small, low-cost arms designed for teaching purposes, as well as an increasing range of industrial arms which are sufficiently inexpensive to bring into the larger teaching districts (Arnold, 1984). Arnold states that these arms can provide sufficient mechanical capability to illustrate many of the major principles of industrial handling tasks. For example, the use of computer interfacing allows the potential for devising and storing complex operating cycles. However, Arnold also warns that "teach-mode" programming may be tedious and the computer interface may limit both the operating speed and the control of the movement when more than one axis is used simultaneously. The suitability of small robotic arms for teaching purposes will depend on the aims of the course. Arnold also thinks that cheap, small robotic arms are simple and safe to use and allow more opportunities for individual practice because they can be purchased in greater numbers.

As opposed to industrial robots the toy robots are more inexpensive and fun. Although they are limited in ability, these robots can be used to demonstrate many robotic concepts. A popular example of this category is Milton Bradley's "Big Track." It has a calculator style keyboard and a memory that holds up to 16 instructions for movement and sound, according to Van Horn (1986). Many elementary

school teachers use "Big Track" to develop LOGO concepts. Toy robots come in a great range of abilities and types. Price varies with the amount of sophistication and by the manufacturer. Due to the price and availability, this classification of robots can be easily incorporated into school budgets for educational uses.

The umbilical robots are usually interfaced through a long cable to a microcomputer. They are usually programmed using LOGO, a computer language, and are frequently called the "turtle." The benefit of these robots is that by using an existing computer for intelligence, there is substantial savings gained in the initial expenditure. However, the umbilical robot does not have sensors and cannot respond to their environment. They merely enact commands received from the attached microcomputer. These robots provide a good source for schools that teach programming to use (Van Horn, 1986).

The study robot is the sixth classification of robots in Van Horn's scheme. they are usually scaled-down versions of industrial robot arms or assemblies. They are similar to industrial robots, mechanically, but lack the precision; they are designed to lift smaller weights. Some study robots can interface to a microcomputer, while others can be purchased in a group large enough to simulate a miniature manufacturing plant or assembly line. Many of these robots

are available with robotic curriculum and all necessary support material which could include textbooks, lab assignments, tests, and activity books. Robots in this class are often geared toward vocational or technical classes at the secondary or junior college level.

The homebrew or homemade robot is the next classification in this scheme. These robots are made by individuals or groups of people who enjoy making mechanical devices. Many large cities have clubs of people interested in creating robots.

A good example of a homebrewed robot is Leachim. Reichardt described Leachim, one of the first educational robots. It is a robot teacher that has been in a New York City school since 1973. Leachim was constructed by Dr. Michael J. Freedman of Bernard Baruch College of the City University of New York. Leachim was designed to help a teacher work with children who exhibited diverse ability levels and attention spans.

Leachim is 5 ft. 6 in. tall, weighs 200 lbs. and stores 200 hours of curriculum. It is programmed with fifty 9- to 10-year-old students' biographies from a school in the Bronx. It can instruct up to five students simultaneously, teaching each student on each student's individualized learning levels through headsets. Leachim's stored memory includes all necessary textbooks, current events

information, a dictionary, a children's encyclopedia, presidents' speeches, as well as students' profiles. Leachim's memory is accessible through pressing buttons or dialing. Leachim answers all questions in a metallic voice. It also gives tutoring in mathematics, science, history, and social studies.

The students identify themselves by dialing their own code number into Leachim. It then greets each student by name and then searches stored memory for information on that student's last lesson. Leachim then reminds the student of what was covered in their last lesson together, and then they start the new lesson. After a question and answer period of about 15 minutes every other day for each child, Leachim again searches the memory banks and totals the student's progress. Based on indicated progress, Leachim will assign remedial or reenforcement work to be completed by the student before the next robotic session. The students find their work sessions with this robot "personal, exciting, and rewarding" (Reichardt, 1978, p. 109).

The last classification of robots in this scheme is the autonomous or personal robot. They are technically true robots, according to Van Horn (1986). These robots contain a microcomputer with "analog-to-digital" interface and sensors, which can include sound, light, heat, and speech synthesis; they also have rechargeable batteries and drive

mechanisms. These devices enable the autonomous robots to move around and interact with their environment. Frequently, "ranging sonar" is used in these robots to locate and determine distance to objects in their paths. Infrared motion detectors can sense body heat and distinguish between animate and inanimate objects. Sound detectors allow the robots to count repetitions in sounds like hand claps. Most autonomous robots are unable to understand spoken words although their sound sensors can respond to the change in sound.

The microcomputer in autonomous robots can usually be programmed in Basic or LOGO and are very similar to typical microcomputers in everyday use. The basic difference between the two microcomputers is that the robots have specialized programs that interface to the sensors, drive mechanisms, and other devices. Some of these robots can be programmed directly through an onboard keyboard and monitor, allowing direct interaction with the robot, while others require the use of an external microcomputer or terminal to program the robots. Once again, by using an external or preexisting terminal for programming, it cuts down on the initial expenditure.

Because the autonomous robot is mobile, has limited sight, and is capable of verbal communication, it has been very popular for the introduction of robots to students of

all age groups. Unfortunately, there is very limited curriculum developed for autonomous robots. For the most part these robots have only been used to allow students a first-hand experience with robots. The best feature, according to Howe (1984), is that students love to program them to move, talk, and perform tasks.

Many colleges and universities are using autonomous robots to teach what several educators call "robotic literacy" courses. These courses teach students how robots work and how to control them with a computer. Many of the courses discuss robot applications in industry since this is the area in which robots are currently used the most often.

There have been many articles written about autonomous robots and their classroom encounters. In order to put these articles in better perspective it is necessary to separate robots by manufacturer and brand name. There were four main types of robots found in the review of related literature currently making the classroom circuit.

All four of the robots have certain basic features in common. They are all battery-powered, have small rubber wheels and electric motors for movement, and have one or more sensors. Tactile sensors are the most common. The tactile sensors detect objects the robot touches through microswitches. When the robots run into an object, they will either stop or turn and try a new direction, depending

on the type of robot. Students can develop programs to assist the robot in avoiding objects.

Some of the more advanced robots have ultrasonic sensors that can locate objects. Ultrasonic sensors transmit high frequency signals that operate like crude sonar devices. They can receive echoes from objects in their path.

Voice synthesizers are another common feature found in the autonomous robots in this review. Language is broken into individual sounds called phonemes and is recreated in a monotone voice. The phonemes are produced in rapid sequence to create spoken words.

The four robots chosen for a more indepth study are Hero, Topo, RB5X, and the Tasman turtle. Each robot will be described by characteristics and a brief explanation of how each type of robot is being used in the classroom today will be given.

Hero. Meinert (1985) gives a detailed account of the autonomous robot, Hero I. Hero I is an acronym for Health Educational Robot. It is a completely self-contained electromechanical robot capable of interacting with its environment. It is controlled by its own on-board programmable 6808 microprocessor-based computer and can detect light, sound, motion, and distance through electronic sensors. It has a mechanical arm that enables it to pick up

small objects. It also has a voice synthesizer that enables it to speak complete words and sentences. It can be programmed to travel over predetermined courses. Hero has a self-contained rechargeable power supply that enables it to function without any external control. The voice synthesizer can generate 64 sounds, with 4 different pitches, to simulate human speech; this allows the freedom to program Hero in any language.

Hero's movements are fluid and relatively quick, according to Slesnick (1984). Its wheels allow it to move forward, backward, left and right. The arm has five axes of motion which are intentionally weak to provide safety in the classroom. It can keep track of time, can detect distance and direction of obstacles, and can count objects or sounds. The sensors can detect sound, can detect motion, and can respond to light.

The literature indicates that Hero must be programmed in machine language through one of two ways. It can be programmed through a cable linked to the on-board computer and attached to a joystick. The joystick controls the movements forward, backward, right or left. The second to control Hero is through the use of a computer program. The program can be entered through an on-board keyboard or stored on a cassette and fed into Hero's memory. Hero is currently being used with students in kindergarten through junior college.

Van Horn (1986) has developed a list of classroom activities for Hero. His activities start with simple introductory lessons for early childhood and range through various subject areas for high-school students. The only limitation of these activities is that they are developed for limited time periods and do not go into great detail.

Howe (1984) states that Hero is an outstanding tool for advanced high-school computer science and college-level classes. He thinks that Hero is too complex for other classes. He justifies this opinion because Hero must be programmed in machine language. This complaint has been eliminated because an optional tape allows Hero to be programmed in BASIC. Slesnick (1984) described a Hero encounter at Pioneer High School in San Jose, California. He said Hero was able to entertain and enchant an entire classroom of 16-year-olds. Hero seems to be a very good all-around robot for junior- and senior-high-school students to use to understand robotic technology.

TOPO. The literature describes a second autonomous robot that has found its way into the classroom, TOPO, a product of Androbot, Inc. It looks more human than Hero. It is the size of a 5-year-old child. It moves in response to program commands entered through LOGO or BASIC in the computer which acts as its brain. There is also a joystick available to control TOPO's movements for pre-literate

children in preschool, kindergarten, or first grade. TOPO can also be interfaced with the Apple II personal computer. Commands are transmitted by radio frequency to TOPO, up to a distance of 100 feet. A transmitter controller card must be plugged into the Apple computer to allow transmission of commands. Moving in response to a student's commands, TOPO performs a concrete motion in response to an abstract thought written in a programming language (Barnett, 1984).

There is a turtle on the computer's screen which mimics TOPO's every move; however, it moves more precisely than TOPO. In fact, TOPO's lack of precision was noted in every article about it. But as Watt (1984) said, it is a valuable educational experience for students to learn to take TOPO's inaccuracies into account when programming it.

Stevens Creek Elementary School in Cupertino, California, uses TOPO with kindergartners through sixth-graders. One of the many things TOPO does there is to help students with estimation. In order to correctly guide TOPO, the student must estimate the desired distance in units and right or left direction; the student must also test hypotheses and make adjustments to the program. The fifth- and sixth-grade students have developed computer programs to make TOPO dance. They have also created an obstacle course in the computer lab and held competitions called "Topo Olympics" to compete with each other in writing

programs to see who can move the robot through a maze the most quickly (Howe, 1984; Slesnick, 1984; Watt, 1984).

TOPO is a more limited robot than Hero for many reasons. The most significant is its lack of sensors; it literally cannot tell when it is up against a wall (Slesnick, 1984). It lacks a voice synthesis unit and does not have an on-board computer; this limits what types of programs can be written for TOPO.

RB5X. RB5X is the third personal robot to enter the classroom environment. It is a cylindrical robot with a dome-shaped top. It stands about two feet tall and is manufactured by RB Robot Corporation (Howe, 1984).

RB5X comes with ultrasonic tactile sensors. There are an optional voice synthesizer and a mechanical arm that has five axes of movement; this arm retracts inside the robot when not in use. The voice synthesis equipment allows phonic construction of words, similar to Hero, except that RB5X can generate sounds similar to whistles, beeps, and simple musical tunes. There are several other options for RB5X under development. They include a voice recognition system, a vacuum cleaner trailer, and a radio communication system.

RB5X can be programmed by interfacing the robot to a microcomputer. The microcomputer uses a software package to permit the machines to communicate with each other. The

software package changes BASIC into machine language, the language of RB5X.

RB5X comes with two learning programs, alpha and beta. These programs let the robot remember paths that take it around obstacles and allow it to try these paths on different obstacles it encounters. Howe (1984) states that RB5X is a robot well-suited for intermediate and advanced high school computer classes since the students' existing computer programming skills can be useful in programming this robot.

Tasman Turtle. The last robot is the autonomous robot nicknamed the Turtle. It is the Tasman Turtle, produced in Australia. It has a clear, plastic, hemispherical shape, rimmed with a rubber touch-sensor bumper. It has eyes that flash on and off, a tooting horn and an optional Digitalker card with a vocabulary of almost 600 words. There is also an optional mechanical arm. The Turtle robot is connected to a computer through a flat ribbon cable. The Turtle contains a solenoid-controlled pen that permits it to draw on paper when it moves (Watt, 1984).

Howe (1984) states that the Turtle's best feature is that it can be programmed in Terrapin and Krell versions of LOGO. He feels that this robot is an excellent choice for elementary and junior-high-school students.

Eighth-graders at the Carey School in San Mateo, California, used BASIC and some special Turtle commands to teach it to draw circles and 12-sided solids. They made the Turtle wink and toot its horn, and within ten minutes they caused the Turtle's pen to run out of ink. Slesnick (1984) feels that the Turtle was able to bring programming problems to life much better than a screen turtle. Students could not ignore real-world problems such as walls and other obstacles in the Turtle's path.

These examples indicate that robots give three-dimensional meaning to a technology that was for years only two-dimensional. The conclusions that can be drawn from this review of related literature are that the robot chosen for educational purposes has to match the student's age group and that it should be complex enough to meet the curriculum goals established.

CHAPTER III

Procedure

The need for the development of this curriculum on robotics has been justified by the review of related literature. Because robotics is such a new field of study, there has not been any in-depth research to assess particular needs as perceived by practitioners. The related literature expressed repeatedly that there is a great need for the development of robotic curriculum in all age groups and in all subject areas.

The need for this curriculum is based on the categories of fundamental skills called Neoacademic skills (Saylor, Alexander, & Lewis, 1981). These skills state that education should include a knowledge of sources and the understanding and use of computer languages. Robotics, according to the review of related literature, is following the evolutionary process that computers have already traveled since robots are soon going to be as prevalent as computers are now.

The content and the cognitive objectives for the robotics curriculum will be devised through an integration of the technical industrial arts courses on robotics and college-level courses on robotics with the already established basic level of robotics education used as an introduction in the elementary school. Both levels have

valid content and objectives for each age group. The rationale for this integrative approach is that since the content and objectives have been developed for one content and are valid, they should be able to retain their validity when adopted for another age group.

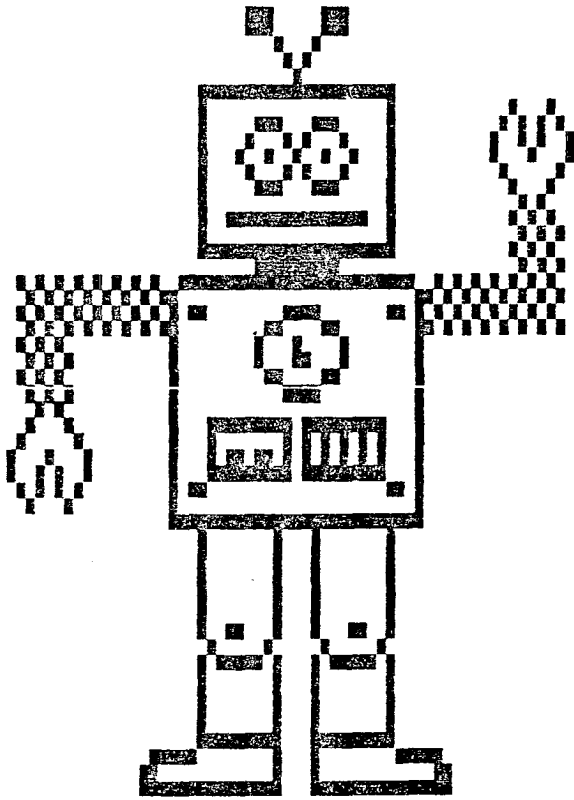
The development of the second guideline used in the selection of content and objectives was influenced by the robots available for use in the classroom. As a result, the content and objectives of the curriculum are specific to Armatron and Hero Jr. since these are the robots available in the Duval County school district.

The learning experiences will be an integration of the technical industrial arts courses on robotics and college-level courses on robotics with the already established basic level of robotics education used as an introduction in the elementary school. The format will follow the eighth-grade state computer course taught in Florida because this format is already familiar to both students and teachers.

The evaluation will be based on a two-part procedure. The first part will be to pilot the curriculum with a group of eighth-grade students at Kirby-Smith Junior High in Duval County, Florida. The students will each be given a pre- and post-test that will be used to evaluate the effect of the curriculum on student achievement. The second part of the

evaluation procedure will be to have individuals who are familiar with the subject, along with practicing teachers of robotics classes, review the curriculum and evaluate it through a questionnaire. The results will be used to make beneficial adjustments to the curriculum.

INTRODUCTION



TO ROBOTS

CHAPTER IV

Curriculum

Lesson Title: Introduction to Robots - Part I

Objective: The students will list at least four characteristics of robots.

Major Idea: Characteristics of robots.

Lesson Style: Taba Model.

Procedure: The students will form a large circle around Hero Jr. Hero will go through the introduction routine. Students will be shown how to use the remote control and on-board keyboard to program Hero. Once the subprograms are set Hero will be allowed to "cut loose."

Phase I: The students will list observations of Hero on the chalkboard.

Phase II: The students will group their observations.

Phase III: The students will create labels for the groups.

Phase IV: The students will describe what is on the chart created in the first three phases. The chart can now be considered a data-retrieval chart.

Phase V: The students will compare the different cell blocks to each other. How are the cells alike or how do they differ from each other? The students will have

to support or justify their explanations in terms of data on the chart.

Phase VI: They will have to explain their observations and generalizations, based on information on the chart. They will compare and contrast groups of cells on the chart.

Phase VII: The students will have to predict or hypothesize about things not included on the chart. Where would new developments in robotics fit into the chart?

Assignment: The students will write down as many types of robots as they can think of. The list must include at least three different types of robots.

Lesson Title: Introduction to Robots - Part II

Objective: Given a list of characteristics of robots the students will be able to identify which are essential to all true robots and which are attributes of some robots.

Major Idea: A robot is a reprogrammable multi-functional manipulator designed to move materials, parts, tools or specialized devices through variable programmed motions to perform a variety of tasks. This definition is from the Robot Institute of America. The key word is reprogrammable, because it refers to a built-in computer control system. A robot must have a "brain," be capable of movement, and be able to perform some task.

Lesson Style: General Deductive Model.

Procedure: The students will be given the Robot Institute of America's definition of a robot. Then the students will use the data-retrieve chart created from observations of Hero to classify characteristics of all true robots and attributes of some robots.

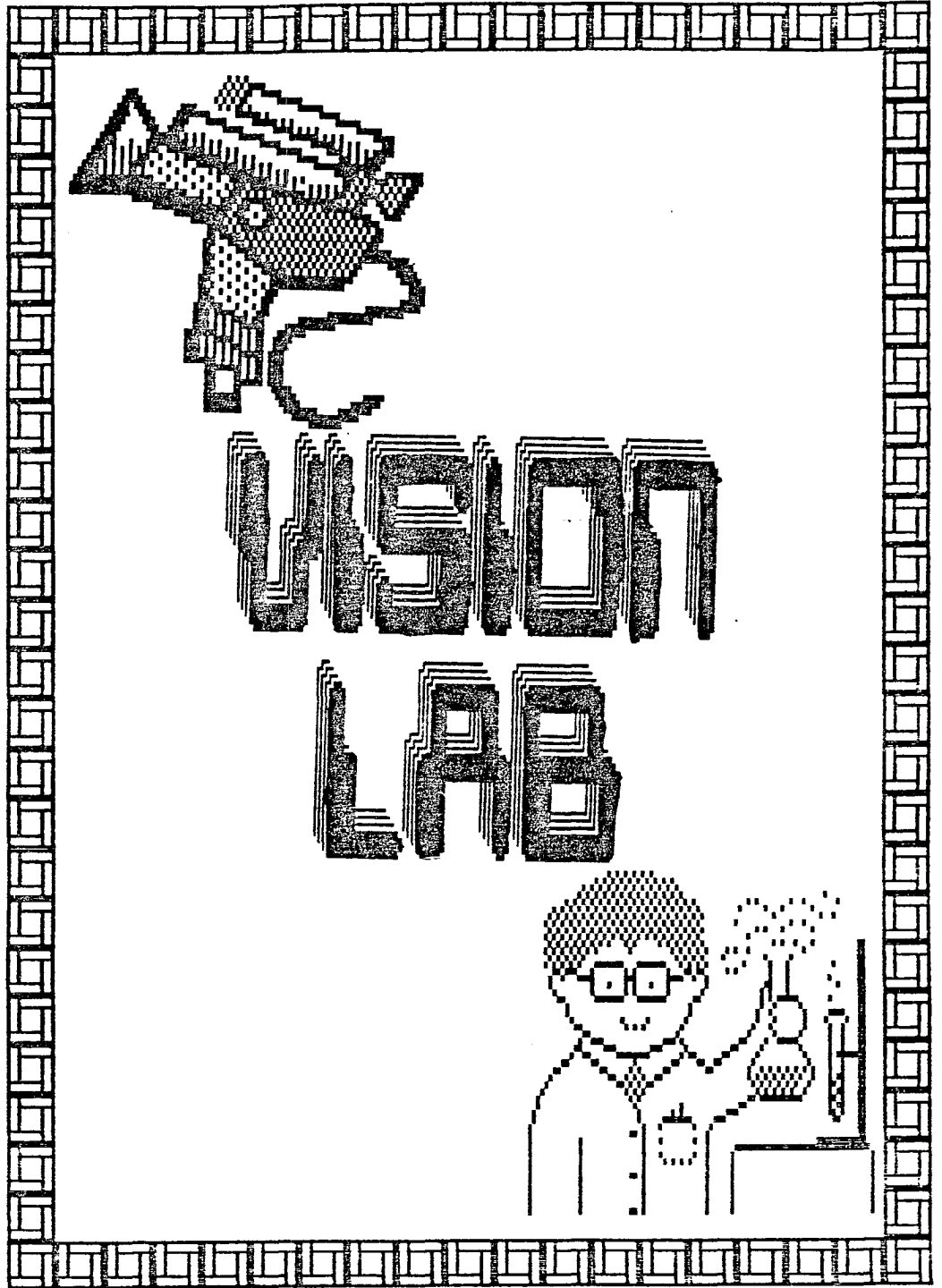
Phase I: The teacher will present the abstraction which is the definition of a robot.

Phase II: The terms in the abstraction are discussed to insure that each student has a complete understanding of what the terms mean. If it is necessary the

teacher will give examples and non-examples of the terms until an understanding is found.

Phase III: The students will generate examples and non-examples from the data-retrieve chart made the day before on observations of Hero Jr.

Assignment: The students will, in writing, decide which of their examples from the previous day's assignment are examples of true robots and which are non-examples. They must list reasons for placing all robots on the non-examples category.



Lesson Title: Simulated Vision Lab

Objective: The students will be able to break down the process of vision into four steps.

Major Idea: The process of vision can be broken into four main steps.

- 1) The eye sees the image.
- 2) The eye transfers the image to the brain.
- 3) The brain translates the image.
- 4) The brain devises a plan of action.

Lesson Style: Suchman Inquiry Model.

Procedure:

Phase I: The teacher will identify the problem by saying, "Some experts say that vision is the biggest drawback to robots. Why should vision cause trouble?"

Phase II: The students will form hypotheses to possible solutions.

Phase III: The students will gather data through a simulated vision lab.

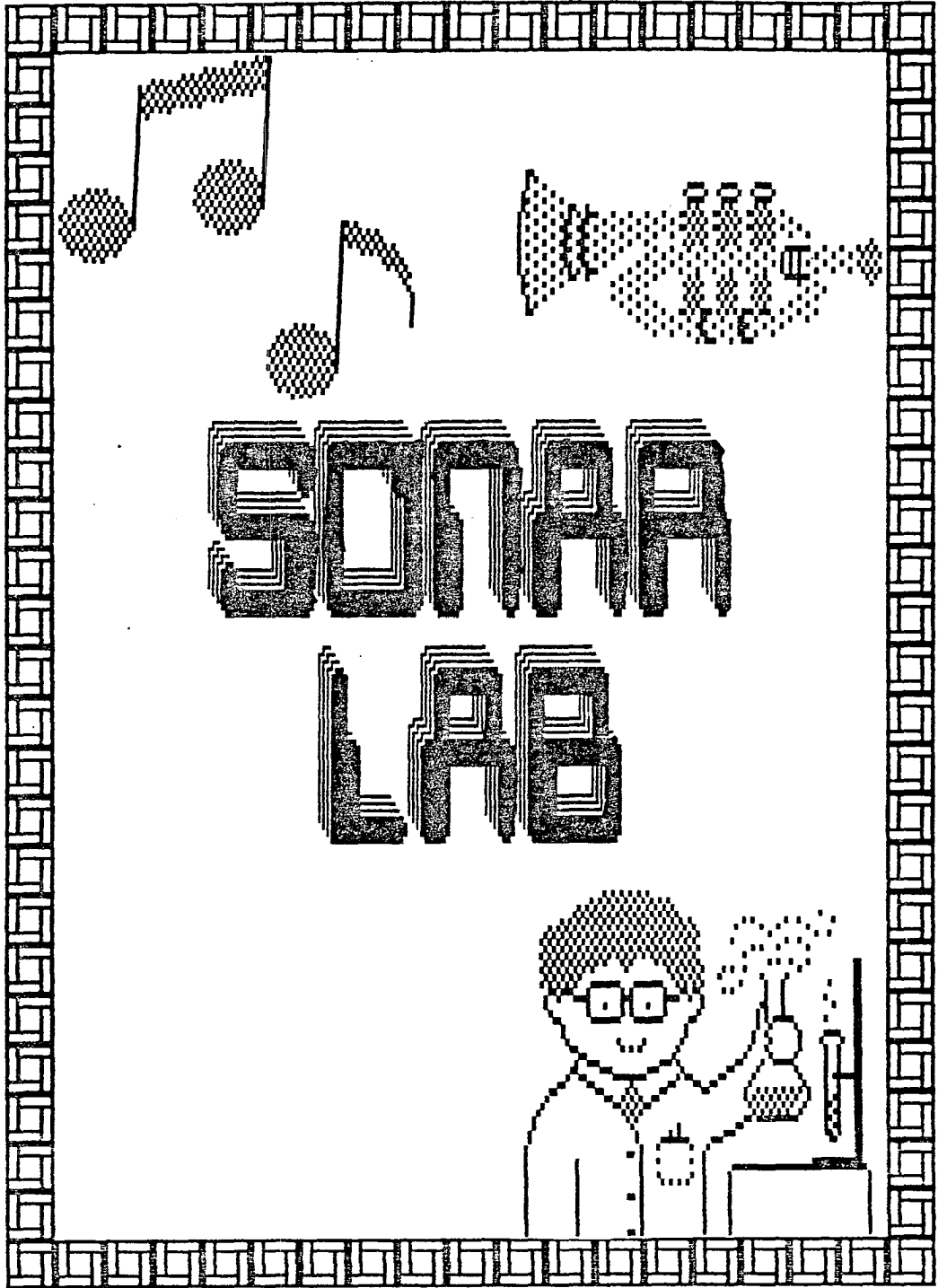
To set up for this lab it is necessary to form a maze in the classroom by using tables, desks and other objects as obstacles. Make sure there is a clear path that starts at one end of the room and ends at another. Have each student draw a number from a hat. This will determine the order the students will proceed through the maze. The teacher will need a V.C.R., camera, and

monitor for this lab. Use an eyepatch or one eye blindfold to blindfold the first student. This will eliminate bilateral vision and distort depth perception. The V.C.R. camera should be mounted on the blindfolded student so that it faces directly behind the student like an eye in the back of the head.

Place the V.C.R. monitor so the student can face it as he backs through the maze. The student will use the camera and monitor as the only vision to move through the maze. This lab enables the students to experience the process of vision in a new way that simulates robotic vision.

Phase IV: The students will revise their hypotheses to fit the data gathered during the lab.

Assignment: The students must describe, either in writing or orally, how the simulated vision made them feel.



Lesson Title: Sonar Lab

Objective: The students will write a definition of sonar in their own words and be able to explain how it can detect objects and why sonar is useful to robots.

Major Idea: Sonar detects the presence and location of objects by means of sonic and supersonic waves reflected back to the source from the object.

Lesson Style: Suchman Inquiring Model.

Procedure:

Phase I: The teacher will identify the problem by asking, "Can sonar be called vision?"

Phase II: The students will form hypotheses to whether or not sonar is vision and why.

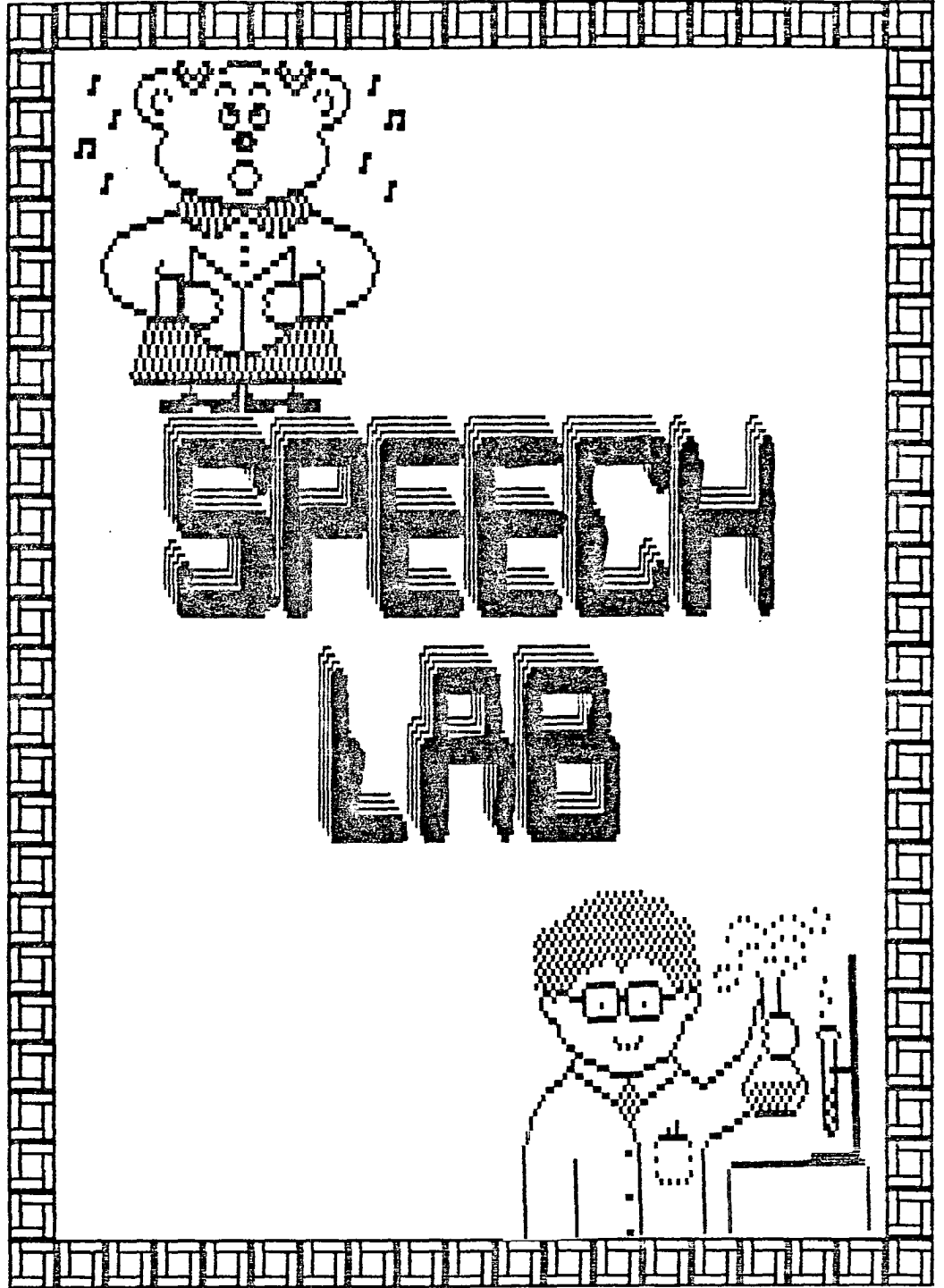
Phase III: The students will gather data through a simulated sonar lab.

To set up for this lab it is necessary to form a maze in the classroom by using tables, desks and other objects as obstacles. Make sure there is a clear path that starts at one end of the room and ends at another end. Have each student draw a number from a hat. This will determine the order the students will proceed through the maze. Blindfold the first student and give each of the other students a party clicker and assign them an obstacle to guard. Instruct them to only click their clickers when the blindfolded student is facing

them and moving toward their obstacle. The students are to stop clicking the clickers when the blindfolded student either hits the obstacle or moves away from it. The blindfolded student is to move as quickly as possible without hitting any obstacles. Rearrange the maze after blindfolding each new student.

Phase IV: The students will revise their hypotheses based on the simulated sonar lab. The students may not all agree whether sonar is vision or not.

Assignment: The students must list at least five different things that use sonar, at least two of them must be some form of mechanical device.



Lesson Title: Speech Lab

Objective: The students will break short common words up into individual sounds called phonemes.

Major Idea: A speech synthesizer generates tiny, basic elements of sound called "phonemes" that when strung together create words.

Lesson Style: General Deductive Model.

Phase I: The teacher will present the abstraction which is the definition of a phoneme.

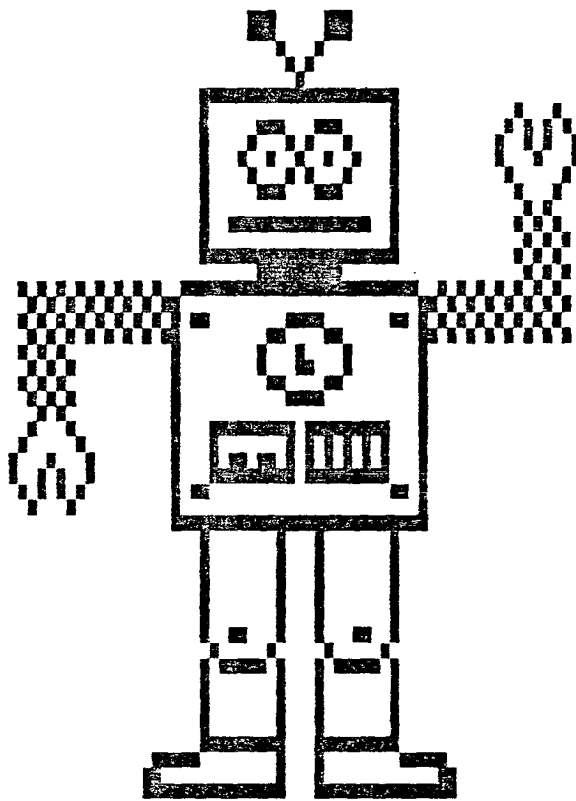
Phase II: The teacher will make sure that every student understands all the terms in the definition. The students need to be reminded that language is made up on sentences fitted together to make sense. They also have to understand that sounds make words, words make sentences and sentences make sense. The teacher should ask questions that reinforce the students understanding of the definition of phonemes. The students should restate the definition in their own words.

Phase III: The teacher will present examples of phonemes used to create words through Hero Jr.'s speech synthesizer. The teacher should choose words that can be used to create other words, for example: into, understand, and forward. The teacher should write each word on the chalkboard and write the code under it and then have Hero Jr. say the word.

Phase IV: The student will generate new words using the phonemes the teacher used to program Hero. Once the new words are generated the students will break the words into phonemes.

Assignment: The students will break a sentence into phonemes for homework. The sentence must use only the words generated in class and include at least seven words.

MOVEMENT



WORKSHOP

Lesson Title: Movement Workshop

Objective: Given the diagram of a robot arm, the students will label the seven degrees of freedom.

Main Idea: A robotic arm has seven degrees of freedom which allow it to function similar to a human arm. Degrees of freedom are the number of independent movements, or the number of arm joints and activators. (There is a labeled diagram at the end of this lesson.)

Lesson Style: General Deductive Model.

Procedure:

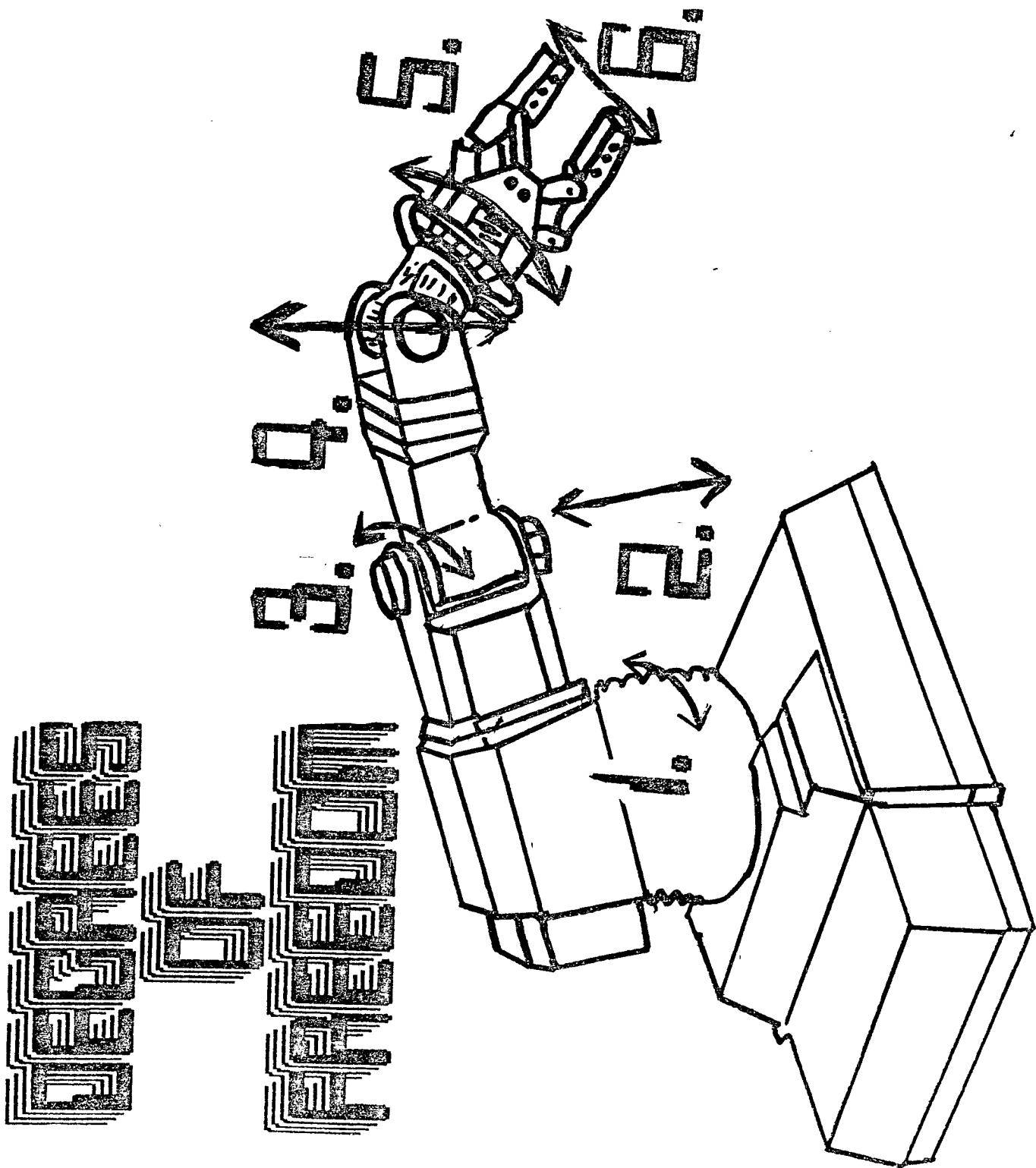
Phase I: The teacher will present the abstraction which is the definition of degrees of freedom.

Phase II: The teacher will make sure that the students understand all the terms in the definition.

Phase III: The teacher will use Hero Jr. as the first example of movement. Hero can only move on one plane. Next the teacher will use an armatron to show how closely it simulates the movement of a human arm. After a demonstration the teacher will ask the students to name the degrees of freedom armatron has demonstrated.

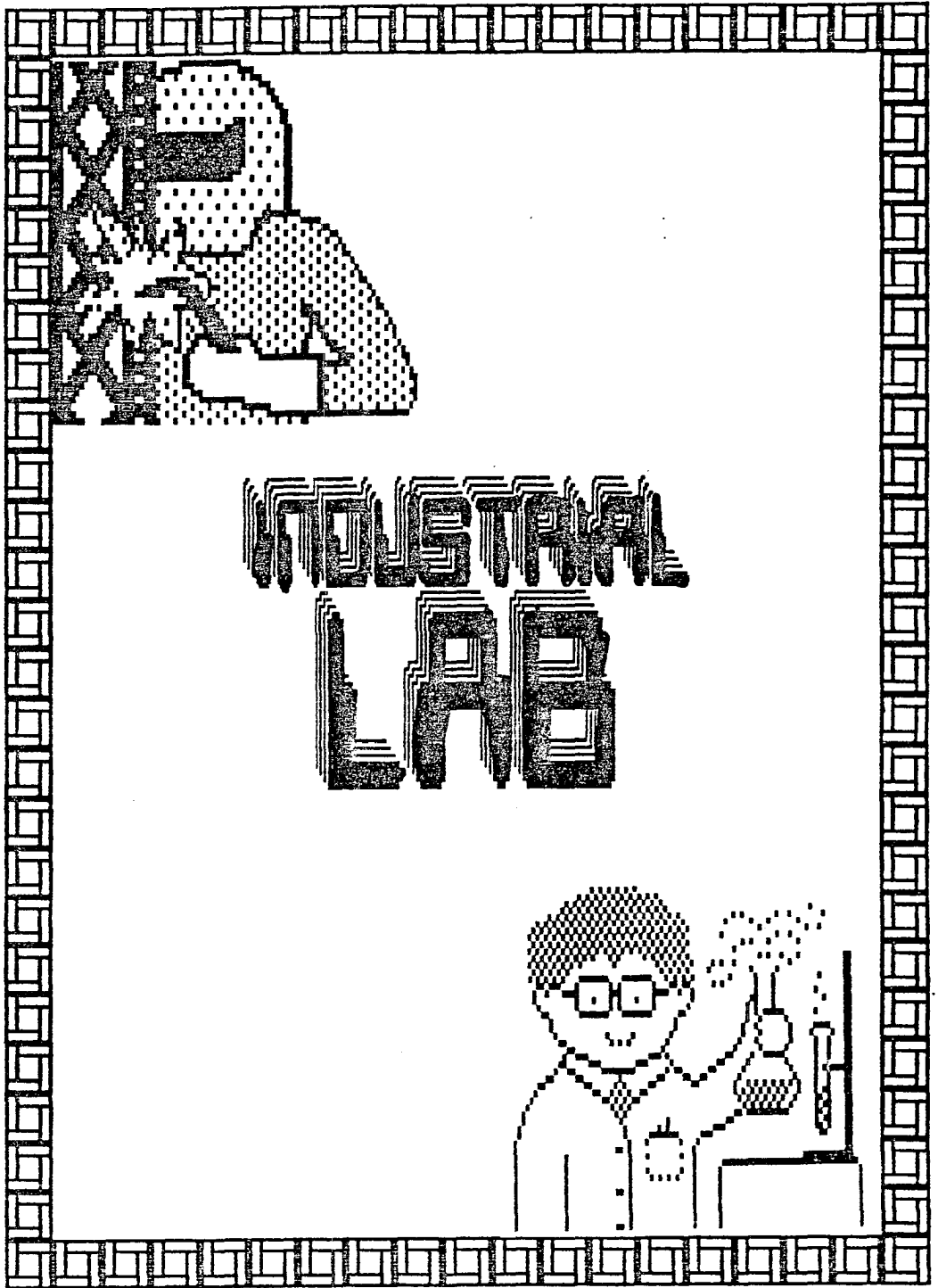
Phase IV: The students will be given a diagram of a robotic arm and asked to assign names to the degrees of freedom.

Assignment; The students will pick one series of movements and write pseudocode for each individual motion in the series. Some examples of a series of movement are:
How to sit down, stand up, run or move an object.



DEFINITIONS OF FREEDOM

1. TWIST
2. RAISE-LOWER
3. REACH
4. LEFT-RIGHT
5. UP-DOWN
6. ROTATE



Lesson Title: Industrial Robots vs Humans

Objective: The students will list at least four reasons why robots are often used in industry to replace humans.

Main Idea: Robots have an advantage over human workers in several ways:

- 1) They free human workers from hazardous environments.
- 2) They lack human needs (money, coffee breaks, food, fringe benefits and they never complain).
- 3) They increase the quality in repetitive tasks.
- 4) They can save energy (lower heat in winter, less ventilation required, they don't need lights to see).
- 5) They can work faster.
- 6) They don't get tired or have personal problems.
- 7) They can work in environments distasteful to humans (hot, dirty jobs).

Some disadvantages to using robots are:

- 1) They are expensive.
- 2) They are unable to make decisions that are not covered in their subprograms. (They lack rational thought.)

The advantages for using robots can be called the 4-Ds: Dirty, Dangerous, Dull, Difficult.

Lesson Style: Concept Attainment Model.

Procedure:

Phase I: Since this is an inductive style of teaching it is important that the students induce the concepts of advantages and disadvantages of using robots in industry. The teacher will show positive and negative examples and allow the students to generate the concept.

The teacher will show two examples of reasons to use robots in industry. One example should be positive and the other negative, they should be labeled positive or negative respectively. An example of two examples would be:

- 1) Removing hot metal from a foundry (adv.).
- 2) Acting as a judge of human action (disadv.).

After the teacher has presented the first two examples the students will suggest possible categories that would encompass the advantages and disadvantages. All suggested categories should be listed on the chalkboard. After the students have suggested as many categories as they can think up, the teacher will present the next example and allow the students to eliminate any categories that no longer fit all the examples. The students may also add any additional categories that seem appropriate.

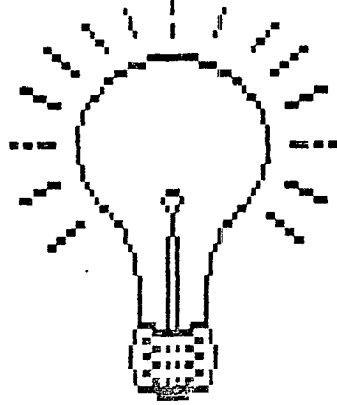
The process of presenting revising categories will

continue until the categories encompass all the examples.

Phase II: The students will analyze the characteristics observed from the examples and make a list of them. They will describe why each characteristic belongs in each category.

Phase III: The students will generate their own advantages and disadvantages to using robots in industry.

Assignment: The students will list seven advantages to using robots and four disadvantages. They must create at least three new situations not discussed in class.



ARTIFICIAL INTELLIGENCE



Lesson Title: Artificial Intelligence

Objective: The students will write the definition of artificial intelligence and list four ways it will change robots and computers in the future.

Main Idea: Artificial intelligence is man-made intelligence and intelligence is the ability to learn, understand and reason. Artificial intelligence will change robots and computers into rational thinking machines. There are three major fields of study for the development of artificial intelligence:

- 1) Giving the robot the ability to perceive its surroundings through sensor systems.
- 2) Providing the robots with a knowledge basis that contains rules stated in "if-then" terms and simulates the decision making process.
- 3) Providing robots with emotions.

These three areas can be called senses, reasoning and emotions.

Lesson Style: Suchman Inquiry Model.

Procedure:

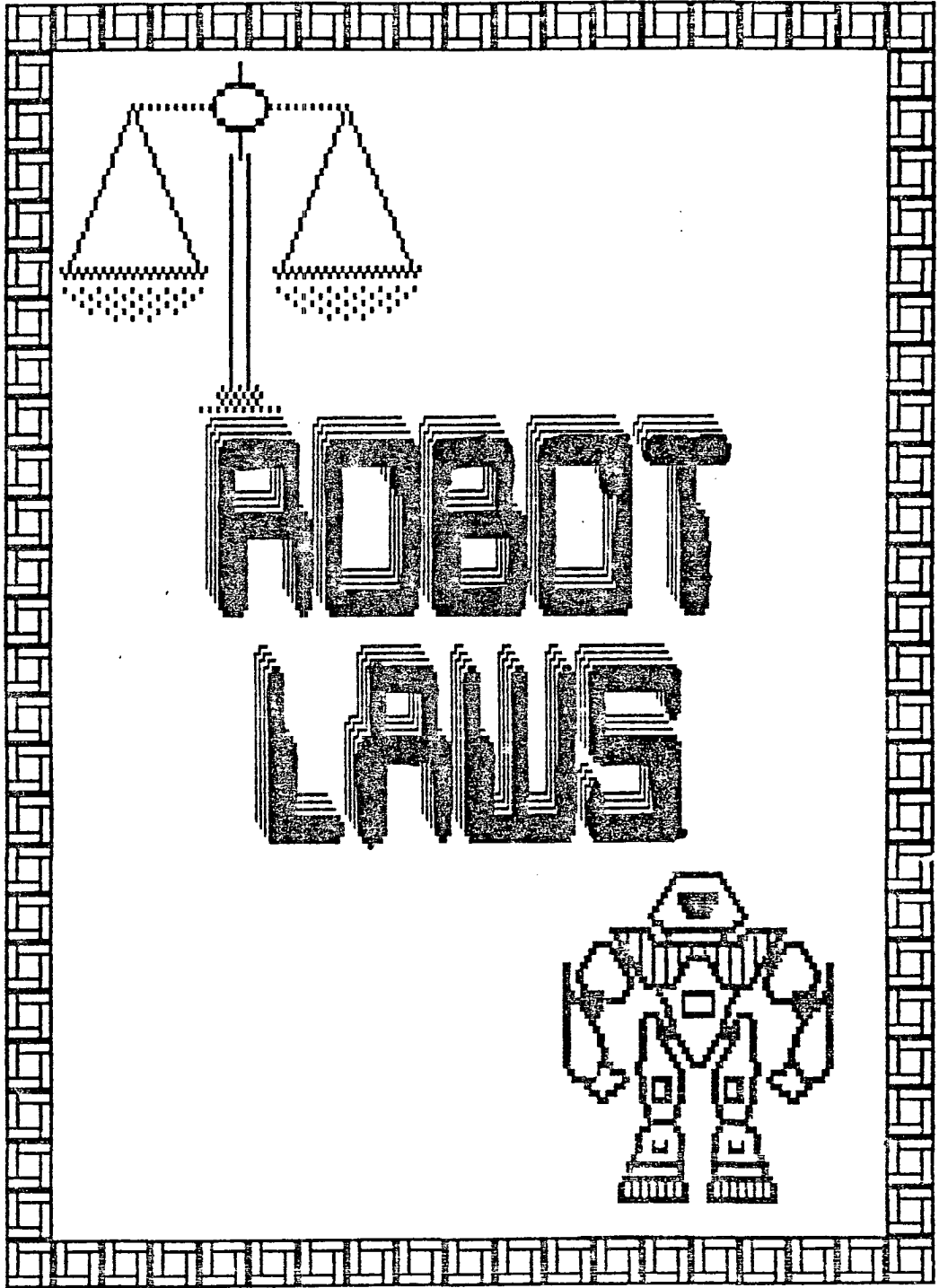
Phase I: The teacher will identify the problem by saying, "Many experts feel that robots are incapable of doing housework without artificial intelligence. What do you think artificial intelligence is and why would robots need it?"

Phase II: The students will form hypotheses as to what they think artificial intelligence means.

Phase III: The students will define artificial and then define intelligence and come up with a working definition of artificial intelligence.

Phase IV: The students will give examples of when robots would need artificial intelligence to perform a task.

Assignment: The student must list at least five jobs not mentioned in class that require artificial intellect for a robot to perform them.



Lesson Title: Robot Laws

Objective: The students will create three laws for robots that will govern the robot's actions and protect humans.

Main Idea: Mankind has several ingrained laws of nature that govern their behavior. Once artificial intellect is developed it will be important to create laws to ingrain into the robots, since robots will not have natural laws to govern their behavior.

Some robot laws according to Isaac Asimov:

- 1) A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
- 2) A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- 3) A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Lesson Style: Suchman Inquiry Model.

Procedure:

Phase I: The teacher will identify the problem by telling a robot story.

High Tech, the first robot with artificial intellect, robbed the First Federal Bank, killed 14 people, stole 2 million dollars, kidnapped a 747 and

blew himself, 40 other people, and all the money up. Who goes to jail since High Tech did all of this on his own with no help?

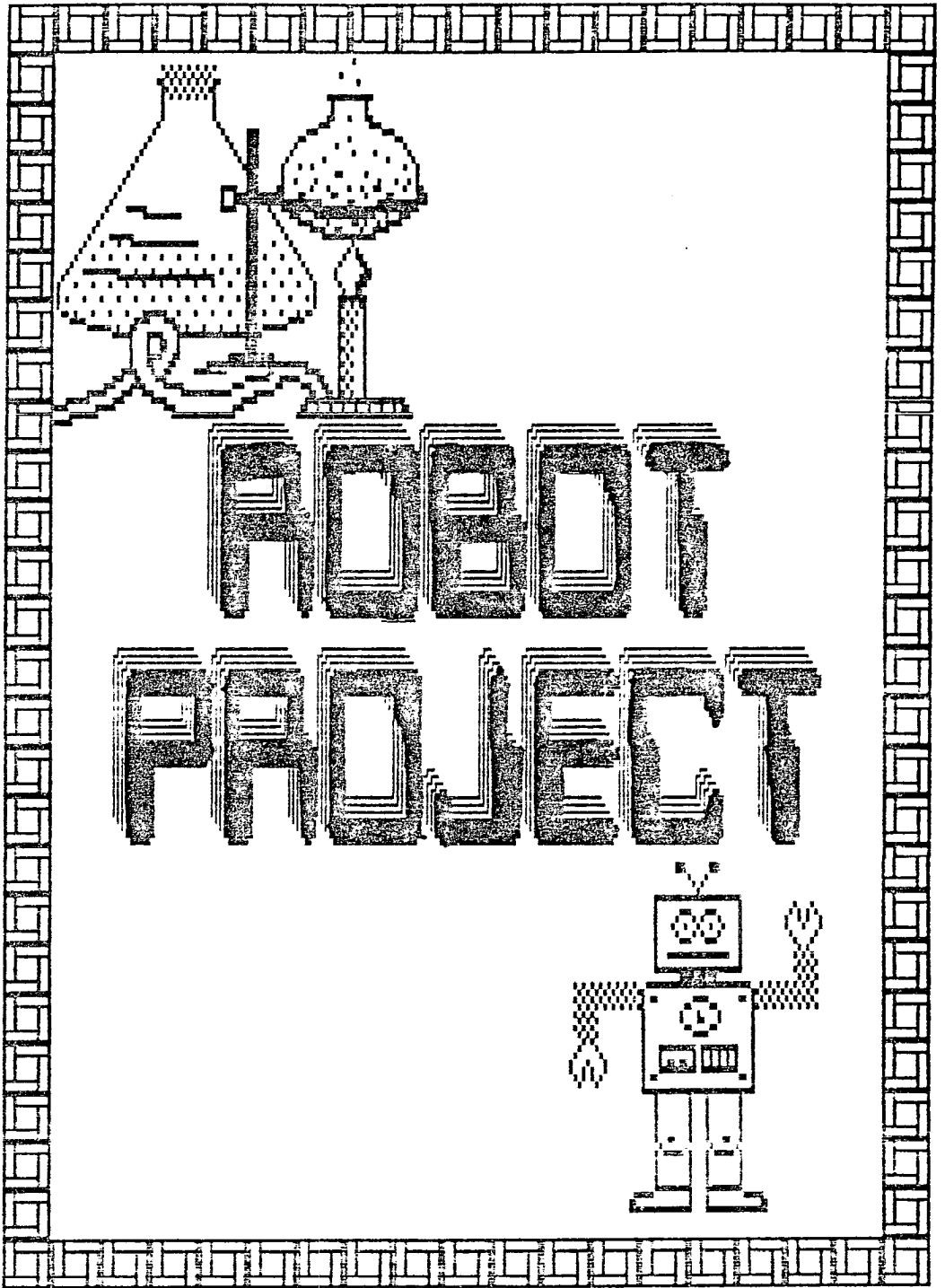
Phase II: The students will form hypotheses as to who is the jailbird.

Phase III: The student will gather data by asking the teacher yes or no questions about the story of High Tech.

Phase IV: The students will revise their hypotheses to meet all the data gathered.

Phase V: The students will develop laws to engrain robots to govern their behavior.

Assignment: The students must in writing tell why High Tech could not rob a bank, murder people or self-destruct if he was ingrained with the robot laws.



Lesson Title: Project Day

Objective: The students will use the concepts learned during the previous eight days to design, develop and present a project that reflects their knowledge of robots.

Major Idea: The major idea is to allow students to use information gathered during this curriculum in a creative and personal way.

Procedure: The students will draw numbers from a hat to determine what order they will present their projects. Each student must have a physical project and give an oral presentation of it. Each student will have a maximum of ten minutes to present their project to the class.

* * *

List of Sample Projects

Write to a Penpal Robot (Dear Robot)

The student must keep a daily diary with a robot as the penpal. They can explain each day's adventures to their penpal (minimum of eight pages).

Robot Friends (Bionic Buddies)

The students have to think of some ways a robot would help in their life. They would also have to interview

family members, friends, and neighbors to find out what they would want a robot to do for them (minimum of eight pages).

Dream Up a Droid

The students would invent their dream robot. It could be two-dimensional or three-dimensional. They must have a list of written characteristics and give detailed accounts of its function.

Robot Dance

The student would invent a dance for a robot to perform. They must write out the movements and perform their dance step-by-step.

Robot Reading

The students could read a book starring a robot and write a book report, give an oral presentation and create some form of art work to represent the main idea of the book.

Robot Speaks

The students can invent a story, song or speech for a robot to perform. They must write the phonemes for the robot and either program Hero Jr. or perform the work themselves (minimum of 25 words).

Robot Games

The student can design a game using Hero Jr. or use an invented robot. The game must have a set of written rules, game plan, and oral presentation.

Robot Show and Tell

The students would use any robot they have at home and explain why it is or is not a true robot.

Program the Robot

Students could write a program for Hero Jr. They must approve the program in advance and have Hero perform the program for the class. They must also have a written copy of the program.

Robot Factory Model

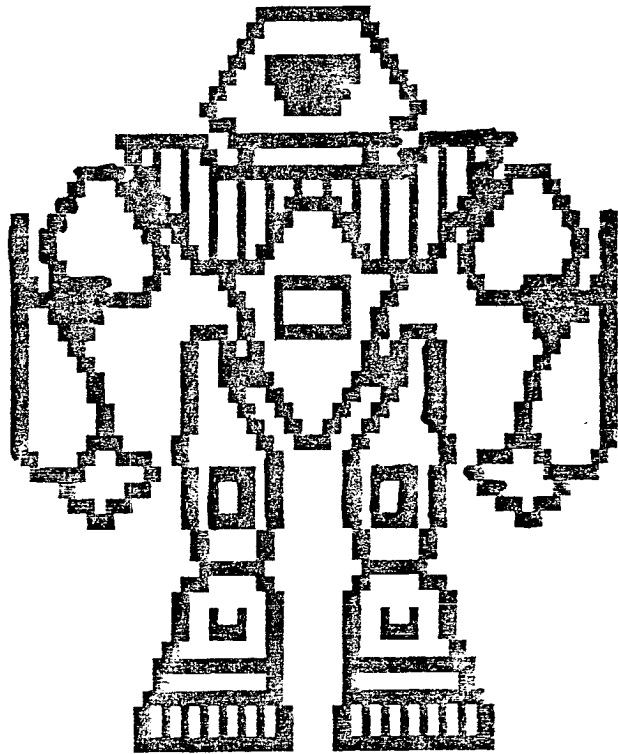
The students could design and build an automated model of a facility that uses robots for manufacturing or moving a part from one point in the assembly to another.

Robot Transportation

The students could design and build a model of a transportation system that uses a robot to move materials.

The students could design and build a model of a robot that mines the surface of the moon, or explores the ocean depths.

ROBOTIC



PRE-TEST

PRE TEST

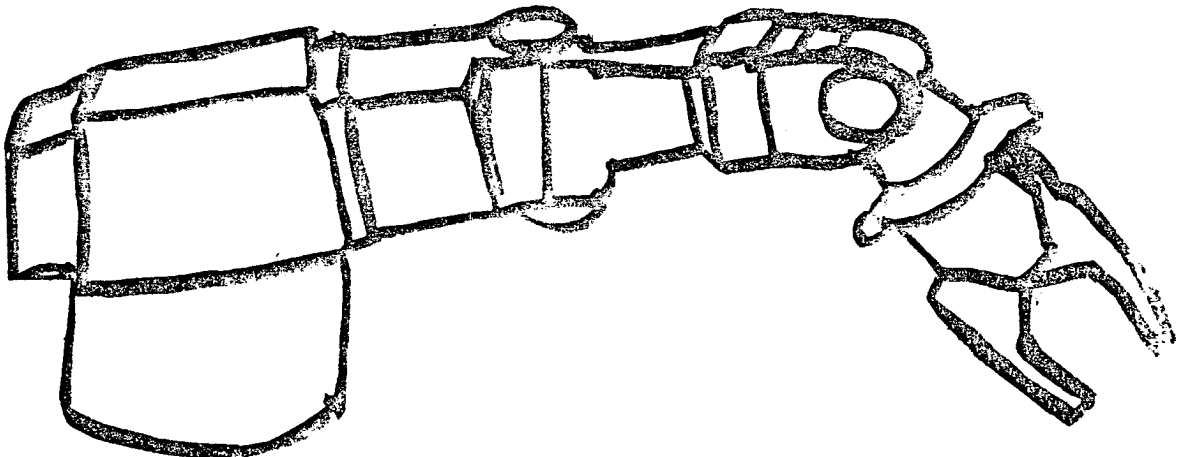
- 1) What is a robot? _____

- 2) List four characteristics of all true robots.
 - a) _____
 - b) _____
 - c) _____
 - d) _____
- 3) List the four steps involved in the process of vision.
 - a) _____
 - b) _____
 - c) _____
 - d) _____
- 4) What is sonar? _____

- 5) What are phonemes? _____

- 6) What are degrees of freedom? _____

- 7) Label at least three degrees of freedom on the diagram.



8) List four advantages to using robots in industry.

a) _____

b) _____

c) _____

d) _____

9) What is artificial intelligence? _____

10) List four changes artificial intelligence will make in robots.

a) _____

b) _____

c) _____

d) _____

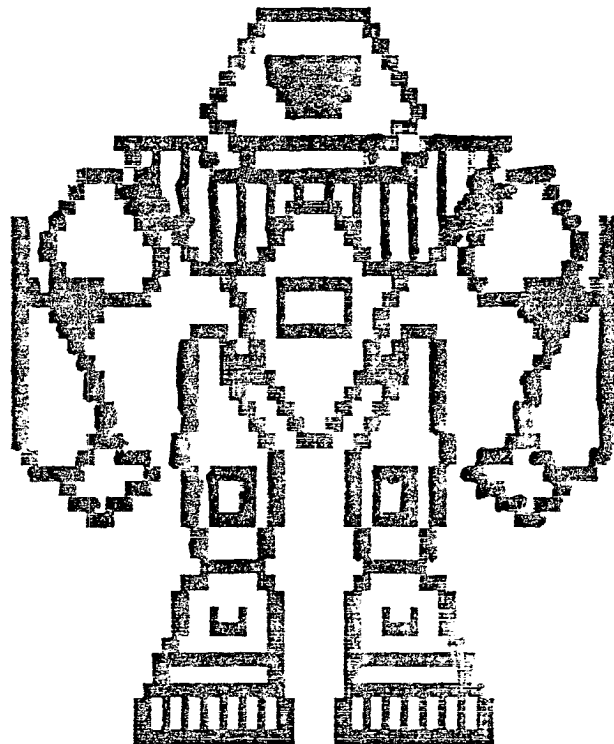
11) List three Robot Laws.

a) _____

b) _____

c) _____

ROBOTIC



POST-TEST

POST TEST

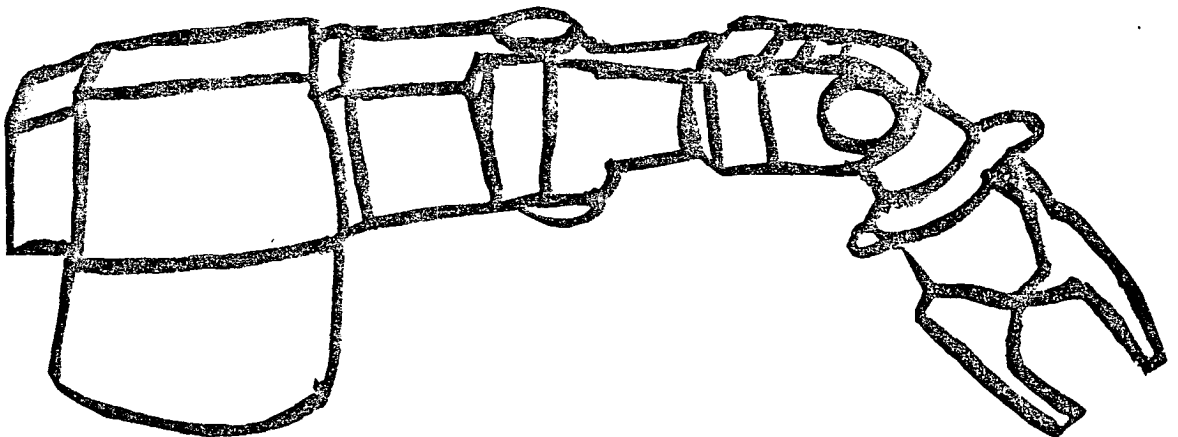
- 1) What is a robot? _____

- 2) List four characteristics of all true robots.
 - a) _____
 - b) _____
 - c) _____
 - d) _____
- 3) List the four steps involved in the process of vision.
 - a) _____
 - b) _____
 - c) _____
 - d) _____
- 4) What is sonar? _____

- 5) What are phonemes? _____

- 6) What are degrees of freedom? _____

- 7) Label at least three degrees of freedom on the diagram.



8) List four advantages to using robots in industry.

- a) _____
- b) _____
- c) _____
- d) _____

9) What is artificial intelligence? _____

10) List four changes artificial intelligence will make in robots.

- a) _____
- b) _____
- c) _____
- d) _____

11) List three Robot Laws.

- a) _____

- b) _____

- c) _____

CHAPTER V

Suggestions for Teaching This Curriculum

This curriculum was developed for eighth-grade junior high school students at a very low social-economical inner-city school. Due to the impoverished condition the students face at home this curriculum does not include assignments that call for use of home computers. If the students come from more affluent life styles it would be easy to incorporate home computers into each day's assignment.

The lessons are self-contained units that can be rearranged and not disturb the overall content. They have been developed to dovetail into each other like links in a chain. The units have also been arranged to maintain the students' interest and provide a varied presentation of materials and teaching styles.

Although several of these lessons were designed for Hero Jr., any kind of educational robot will work just as well. If there is more than one robot available for classroom use it would be easy to contrast and compare the robots to each other and develop the same concepts.

The project presentation day could be either one day or more, depending on the number of students presenting projects and the amount of time each student spends presenting their project. The project unit could be

expanded to a week or more if time permits. Writing skills and library skills could be developed and re-enforced during this unit. The projects could be more difficult for more advanced students or less difficult for younger students.

The Pre-Test and Post Test are composed of the same test items, this serves as a way of checking learning acquired during this curriculum. The results of the Pre-Test were compared to the results of the Post Test and used as one source for evaluating this curriculum. The test items are arranged in the same order as the materials were presented in the curriculum. It is not necessary to use the Pre-Test or Post Test and using the test results as major grades is not required since they were developed solely as a source to evaluate this curriculum and not as a test of individual student achievement.

A good source of more information on robots is Isaac Asimov and Karen A. Frenkel's book on robots, Robots: Machines in Man's Image. Unlike most books on robots this book is not only technical or factual, it is written in easy to understand language and it is packed full of good ideas.

CHAPTER VI

Conclusions and Recommendations

The conclusions and recommendations are based on a comparison of the results of the Pre-Test to the Post-Test and a field test of the curriculum. The field test was conducted at Kirby-Smith Junior High School in Duval County. Kirby-Smith is an inner-city school of predominantly minority students from very low social-economic backgrounds.

The students enjoyed the lessons with Hero Jr. more than any of the other lessons. The students seem to grasp concepts enacted by Hero quicker than any of the others. Many of the students expressed the desire to adopt Hero as a younger sibling. It is strongly recommended that as many lessons as possible be developed to use Hero Jr. or any other educational robot.

The introduction unit to robots that used Hero Jr. went very well. This was a good way to introduce robots because it caught the students attentions and enthusiasm. The students had to give their complete attention in order to understand Hero. It would be wonderful to have more than one robot do this introduction.

The sonar lab went very smoothly and worked well. All the students were able to participate at all times and no one was left out of the action. Since each student had to either guard a post or run the maze, everyone's total

attention was required.

The vision lab, unlike the sonar lab, did not require total attention from the students all the time. Much of the students lab time was spent as an audience. Since only one student could run the maze at a time, it left the other students as an audience. Unfortunately, this age group does not make a very good audience. In order for the vision lab to work well there needs to be no more than 10 students involved at a given time. This number was arrived at by trial-and-error. The groups could be enlarged with a more mature setting.

The movement lab went fine. It would work even better if each group of 4-6 students had an armatron of their own to experiment with. It would be ideal to let one student move an object with armatron and have another student write down the degrees of freedom used and the order the freedoms were used. The students enjoyed performing robot moves very much. Once they understood the process of robot movement, many of the students got quite elaborate with their movements.

The lessons on artificial intelligence and robot laws turned out to be a very important addition to this curriculum. Due to the commercialization of fictional robots through cartoons, toys and movies students were completely unaware of what true robots were or what they could actually do today. There were several students that

expressed fear of robots because of the fictionalization of "man-killer" robots. Once the students realized that artificial intelligence is not perfected or currently used by robots, they understood the need for universal robot laws. Many students expressed a feeling of security associated with engraining robots with laws. There were a few students that felt the armed services would never agree to the robot laws.

The unit on industrial robots generated some good concept development. The students were able to generate the advantages to robots on their own. They also generated many of the disadvantages, some that were not even developed in the unit plan. The students became very involved with the process of when to use and not use robots and when to use only humans. They decided to write a story about human workers vs. robots.

The project day was stretched to two days to allow more time for each student's presentation. It is recommended that an assignment that relates directly to the students robot project be added to each unit in this curriculum. For example, on the first day give the students a list of sample projects and let them pick three they might be interested in working on. The next day's assignment should involve starting the written part of their project. By including project related assignments to each day's unit, it will

ensure higher quality projects and allow the teacher to keep track of where each student is in the development of their project.

The comparison of results from the Pre-Test and Post-Test reinforced the general feeling that this curriculum aid accomplished the goal of teaching general concepts relating to robotics. These tests were not designed to evaluate individual student's accomplishments, but rather to evaluate this curriculum. No students scored 80% or higher on the Pre-Test, while 92% scored 80% or higher on the Post-Test. This seems to indicate that this curriculum did develop robotic concepts in the majority of students.

It can not be stressed strongly enough the importance of education keeping pace with the development of new technologies. We can not afford for education to lag behind or ignore new developments in techniques, because society changes with each new development and education must keep pace with society. Robotics is just one of the new technologies that need to have educators develop curriculum for it. There are many others. With the development of artificial intelligence, education will be faced with a whole new dimension of challenges, which makes it very important to get started now, on existing technologies and add each new development as it is formed.

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