Building Interest in Math and Science for Rural and Underserved Elementary School Children Using Robots

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Abstract

The *Robot Roadshow Program* is designed to increase the interest of elementary school children in technical disciplines, specifically math and science. The program focuses on children from schools categorized as rural or underserved, which often have limited access to advanced technical resources. We developed the program using robots as a vehicle to get children excited about technical disciplines. We have found that while robots are universally captivating for all school age children, they dramatically peak the interest of K-6th graders. During the 2002-2003 school year, more than 1200 children, mostly from rural and underserved Kansas schools, have participated in the program.

Introduction

When the Kansas territory was first settled, those who went to school often attended traditional one-room schoolhouses. While these one-room schoolhouses were normally short on supplies, they generally provided a reasonable and effective education. Although the students were attentive and worked hard toward their academic goals, they were often lacking the resources available in larger cities and metropolitan areas. The school buildings were typically constructed of whatever materials were available and reasonably inexpensive [1]. Given the lack of resources to build the actual buildings, it is easy to imagine the other resource deficits that existed in small schools, when compared to larger urban schools and districts. Although the situation has improved somewhat, there is still a resource gap between larger and smaller schools. While the one room school houses of old have evolved into modern schools with improved access to information, the fact still remains that declining population, declining tax base, shrinking enrollment, less money and strained resources have put a squeeze on all but the most necessary equipment and subjects in smaller towns and school districts [2, 3]. As an example of phenomena of declining population in rural Kansas, we examine data from Wichita County in far western Kansas, where the loss of income producing individuals has had a compounding effect. Not only are the people gone, so is the disposable income they spend in the local economy. Wichita County generally experienced an increase in population from 1920 until 1970, at which time the population hit its high point. This approximates the shift in Kansas population from rural to urban areas, where the rural population peaked around 1930 and has steadily declined since [4]. Within these constraints, the students of rural schools must still compete to find a place in an ever increasing global economy dominated by workers with the ability to apply advanced technologies and solve more complex problems than before [5].

This program was founded on the principle of enhancing the education of children attending schools with limited access to resources and technical programs. The *Robot Roadshow Program* is our attempt to provide a creative method to extend the scientific and math education of these students [6]. In the first, full year of the *Robot Roadshow* program, we visited many schools and involved more than 1,200 children in the program.

The *Robot Roadshow Program* uses a three-step process to accomplish its goals. The initial step is to send grade appropriate, Pre-Visit Workbooks, which help to develop an appropriate set of skills and knowledge necessary to derive the most value from the program. The second step is the actual visit, where the robots interact with the students in a series of experiments designed to reinforce scientific principles in a fun and exciting way. The final step is a follow-up session with the faculty to evaluate overall impact and record demographic data about the student population. We use this information to determine any improvements we need to make to the program and to try and better understand the needs of our target audience.

Overall, we have found that the robots are universally interesting subject matter with school children of all ages, but really peak the scientific interest of students in the K-6 range. Given that this is a long-range program, measuring the overall program impact will require us to follow the participants over a number of years.

There are incentives that exist, not only for the target audience of school children, but also for those participating in the production of the *Robot Roadshow Program*. For faculty, there is a service and outreach component that is helpful in tenure accomplishment and funding opportunities. For the department and College of Engineering, the program is effective in recruitment, creation of goodwill, and good public relations with the school districts that send students to Kansas State University. For undergraduate and graduate students, the program presents an opportunity for participation in a fun activity that allows development of interpersonal skills, public speaking abilities, management of a program and research and publication possibilities.

In this paper, we first review the initial founding of the program and its overall goals. Then, since the exact definitions of *rural* and *underserved* schools are not well accepted, we describe our definition and provide an overview of the program's target audience. Next, we will overview the program's three-step delivery process followed by a discussion of the impacts and results from the first year of the program. We conclude the paper by outlining the future work we have planned to continue to support and improve the program in our attempt to provide the increased educational opportunities for the children served by the program.

Initial Development

This program got its start from Cub Scout troops interested in robots. Additional requests for demonstrations and programs from groups sparked the idea to formalize the program into a stable and reproducible program. The results were so positive that we decided to extend it as an outreach tool for local schools that would not normally have access to these types of expensive teaching and instructional resources. We contacted several schools to determine if the program would be a viable and welcome augmentation to the normal science and math curriculum. The response was positive in every inquiry. At this point, we developed the basic program outline and the initial pilot program was tested on two classes of second graders at a small school in Manhattan, Kansas. After completion of the pilot, we conducted a follow up with the teachers to determine the program's value and to solicit ideas for improvements.

The pilot program generated some feedback that allowed the program to evolve in a positive direction. Some notable changes were the segmentation of the *Pre-visit Workbooks* by grade level as Kindergarten students cannot read whereas 6th graders are normally effective readers. In the pilot, it was discovered that we needed to discuss robots in terms that the children understood, so we included the lecture about how robots are modeled after humans and in particular, children. This created a point of interest and linkage for the students. Following the pilot program, the general visit day format was developed.

Program Goals

We have augmented the goals of the program to include new areas and to extend the program to different student populations. However, the initial core goals of *Reinforcement, Access, Enjoyment, Linkage (REAL)* still exist. We have extended the program to focus on specific subgroups of children, such as females and children with learning disabilities.

Reinforcement

This program must contain a process to reinforce the experience, so that after the visit the child's interest does not deteriorate. The success of the reinforcement goal is critical to enabling a long-term effect on the students involved. The key to success for the *Robot Roadshow* program is to provide reinforcements to learning via a performance-reward linkage. A student will act in a certain way based on the expectation of a certain attractive outcome [7]. The reward or outcome is to see an interesting presentation and participate in a set of hands-on, interactive experiments and departure from the normal school day. The performance they have to provide is to complete the *Pre-visit Workbook* and participate in the interactive experiments.

Enjoyment

Many students in pre-kindergarten through high school do not view math, science and other technical disciplines as fun and subsequently do not pursue them as possible careers. Allowing students to enjoy math and science is critical if the long-term goal is to not only create interest and understanding, but also inspire them to become engineers or scientists.

Access

This program was created to provide an opportunity for underserved or rural schools to have access to additional learning resources in the areas of math and science. Many schools struggle with budget reductions and lack of overall resources. Our program will fill resource gaps with enjoyable access to special technology education.

Linkage

The combination of the previous two goals, *Enjoyment* and *Access*, support the third goal of *Linkage*. *Linkage* allows students to build a relationship between fun subjects, such as robotics, and the study of math and science. This goal's purpose is to provide the necessary performance-reward linkage.

Subgroups

As we have gained experience with the *Robot Roadshow*, we targeted new subgroups such as females [8] and children with autism [9, 10] or Asperger Syndrome. In reviewing and targeting these groups, we believe we can increase program impact. For females, we are attempting to encourage young women to pursue technical disciplines, and not automatically discourage them, based on societal pressures, because of their gender. For autistic children, we hope to give them an additional experience to relate in a world where social norms may be challenging, but robots are an easy "on-ramp" to learning and exploring the environment.

Rural and Underserved Schools

This program was founded with the idea of extending and augmenting the education provided by rural or underserved schools in math and science. As the success of the program has grown and we have gained experience, we have developed a more complete set of criteria for judging what is considered a rural or underserved school. To classify a school as rural, we have adopted the stance that the school population area (the county or city served) must be less than 8,000. In actuality, most of the children we have worked with reside in towns much less than 8,000. When we initiated the program, it was more difficult to determine what constituted an underserved school. The criteria we have developed is based on the number of children in the school that receive free or reduced-price lunches, which is the measure used by the Federal Government for similar purposes. An underserved school can be either rural or urban in nature.

Process

The Robot Roadshow delivery process, as shown in Figure 1, has remained basically the same through its initial year. The process has three delivery elements. *Pre-Visit Workbooks* are sent to the school a couple of weeks before the actual *Visit Day*, which is the actual program delivery. *Follow-up* involves asking for feedback from teachers and collecting student tracking information.

Because the program is offered to a range of children in multiple grades with different levels of technical and scientific understanding, elements of the program are segmented and directed at the target audience. Although the visit day program is fairly standard for all from Kindergarten through 6th grade, the Pre-visit workbooks different. Whereas the higher grades can read, the lower grades are given workbooks that are less skills oriented and more creative. For the younger grades, they are to complete the workbooks with the help of a teacher or parent.

Pre-visit Workbooks

Each child in grades from kindergarten through 6th grade receives a workbook with exercises to prepare them for the visit day. The exercises are created to be interesting and fun, but rigorous enough to prepare the children for the experience. The exercises range from instructing the students to draw and label their own robot, to word searches, to asking the students to compare the intelligence of humans and robots. These exercises are done in a non-threatening manner and are not scored for accuracy, but used as a tool to create familiarity and comfort with a somewhat technical subject. A general example of the pre-visit workbook for elementary students is displayed in *Appendix A.*

Figure 1: Delivery Process

Visit Day

The visit day program normally lasts about one hour per group of children. There is a set agenda, detailed to the minute, followed to deliver the program. It leads the students from a basic introduction to the robots to the point where the students actually participate "hands-on" with the robots in a series of experiments. The agenda for a visit day has evolved into a compact program delivering strong tutorial and interactive, experimental content. The visit begins with introductions and explanation of the program agenda. The program is split into three parts. We begin by comparing robots with human intelligence and function through a short lecture period with questions and answers. Then we show a NASA movie with robots venturing to Mars as a way to describe the future and possibilities not only of robotics, but also as a scientific area in which they can work. The capstone experience is a set of experiments to allow the children to have a sensory experience with the robots. The general agenda is identical for all K-6 students.

Lecture and Q/A

During the introductory lecture, we discuss human and robot intelligence, then progress into learning and finish with sensors. In each phase, we compare and contrast how humans use these capabilities to the way a robot is built and how it will use these capabilities.

To begin the lecture, we compare and contrast human versus robotic intelligence. The discussion is initiated by posing a question to all of the children, "Which is smarter, any person in this class or the world's smartest robot?" We ask for a show of hands to gauge the audience's answer. We discuss, in general, the differences in intelligence between humans and robots. We then move to ask for a volunteer and ask the crowd who will win in a foot race between the volunteer and a robot if both were given the specific direction to run from one side of a room and exit the doorway of the room. We tell the students to assume that direction, velocity and acceleration are the same for both robots and humans. Then we take another poll to see which of the participants, human volunteer or robot will win the race to the door. We ask reasons for belief of why the robot or human will potentially win. We then ask the volunteer if they know what a "door" is and explain that a robot will not know what a door is and this is why the human will win the race. We emphasize that humans will win not because of functionality, but because of their knowledge of the environment.

The next topic of discussion is how we, as humans, generally learn. We talk about how our brain, in conjunction with each of our five senses, allows us to learn almost continuously from our environment. The nature of each sense is reviewed and we talk about how our brains can automatically switch from using one sense in one situation, to using another in a second situation. We use the example of waking up in a dark room in the middle of the night with a goal of making a visit to the bathroom to show how humans use our senses in ways similar to the way that robots use their sensors. The first task is to locate the light switch. We ask the children what sense they would use to find the light switch in the dark. Most say touch, as they will need to reach out blindly to find the wall, even though they have a mental map of the room. We then discuss that once the light is switched on, the sense of touch is no longer primary and vision is used to navigate. We then tie this into what the types of sensors a robot can potentially possess and describe the AmigoBot robot shown in Figure 2, which is the standard robot used in our program.

Figure 2: AmigoBot Robot

NASA Movie

The movie we show visually describes a potential Mars project using biologically inspired robots, from the field of biomimetics. The NASA *Entomoptor* [12] movie shows a spacecraft flying through space, moving into Mars orbit and landing on the Mars surface. After a successful landing, a team of robots unfold and starts to explore the planetary surface. The main idea of the movie is the nature of the robots. There are robot base stations that look like standard Mars rovers, which are accompanied by winged robots similar to butterflies or birds that explore the surface with greater speed and capability. The movie is entertaining and builds a linkage to how interesting technology can be and what is possible for the students.

Experiments

The experiments used during the program involve the students in an active learning instead of a passive lecture. We find the interest is much higher with this format. The experiments involve the use of two AmigoBot robots [13]. The AmigoBot is a low priced intelligent mobile robot. It can be used in a completely autonomous format, which we employ in the experiments. For motivation, the AmigoBot has two 4 inch solid rubber tires driven by reversible DC motors. The AmigoBot senses the environment using eight sonar units to determine the distance to objects. The AmigoBot's brain is a Hitachi H8 processor unit that manages all low-level and electronic systems of the robot. The onboard operating system, AmigOS, is stored in the permanent flash ROM.

We have worked through several designs of these experiments to evolve the current set, which include *Robots Roaming, Escape the Circle, Robot Race* and the *Multi-agent Race.* We discuss each of these experiments below.

Robot Roaming

In the *Robot Roaming* experiment, we link the discussion of sensors and the image the children see of the robot moving around and not crashing in to any objects. The goal is to show how the robot uses its sensors to navigate and avoid obstacles. We have the students sit on the floor, spaced two to three feet apart, and simply put our Amigobots in "roam" mode as shown in Figure 3. The Amigobot uses its sonar to detect the children and avoid them while wandering around the room.

Figure 3: Robot Roaming

Escape the Circle

The goal of the *Escape the Circle* experiment, as shown in Figure 4, is to show the student the difficulty an uninformed robot has at doing even the simplest of tasks, in this case, navigating to escape from a small circle made up of the children. We place the students, side by side, in a circle on the floor with an opening of four to five feet on one side of the circle. Again, the Amigobots are placed in "roam" mode and set in the center of the circle. Eventually, they find their way to the opening and escape the circle. We then discuss how easy it is for a human to escape the same circle in order to compare human and robot intelligence. The experiment is related back the previous question of which will escape the room first, our volunteer or the robot.

Robot Race

The *Robot Race* is an extension of the *Escape the Circle*. In this experiment, the children are split into two teams each having a robot to represent them. Both robots are started as far away from the opening in the circle of children as possible. That team whose robot escapes the circle first is declared the winner. Not only does this experiment result in a lot of noise as the students cheer on their robots, but after one or two experiments, the children inevitably find that they can "guide" their robot toward the opening (or conversely the other robot away from the opening) by extending their arms to make the Amigobots believe there is an obstacle as shown in Figure 5. Normally this experiment is repeated multiple times to show that there is no advantage from one robot to another. The process of random discovery is presented as the robots do not make plans or look ahead to escape, but only escape if they randomly roll from the circle.

Multi-agent Race

The Multi-agent Race is an extension of the Robot Race, except this time we involve students. The goal is for a team, involving a robot and a differing number of students, to work together ("guiding" their robots) to escape the circle. In this exercise, the multi-agent team, of humans and robot, works together to supply attributes each possesses to achieve the goal of escape. The strong attributes of the robot as the central device and the humans as navigators and thinkers are employed. The experiment is performed with combinations of the robot and 1 to 4 students. Each iteration yields a discussion to determine if adding a new person helped or hindered the team. The performance is evaluated by the length of time it took to exit the circle. The effect of the team's organization and how the team plans are discussed. By conducting this set of experiments, we can also teach a simple example of the scientific process and evaluation.

Figure 4: Escape the Circle

Post Visit Evaluation and Tracking

The purpose of the Post Visit Evaluation is to record and evaluate the teacher's perspective on ideas to improve the program. We solicit their feedback on appropriateness of the Pre-Visit Workbooks and the Visit Day content. We also discuss other engineering extension programs, offered by Kansas State University, which may be of value to their children.

Figure 5: Robot Race

Impact and Results

In its first year, the Robot Roadshow was delivered to 1,215 rural and underserved children within the state of Kansas. Most of the schools visited were within a two-hour drive from Manhattan. The 1,215 students included 243 from urban schools and 972 from rural schools, as shown in Figure 6. The breakdown by sex for the participants in the program is shown in Figure 7 with females representing 53.8% of the audience and males representing 46.2%, respectively.

Distribution

In Figure 8, we show the racial origins of the participants. Representatives of five groups participated in the program: African-American (4.7%), American Indian (0.5%), Asian (0.6%), Caucasian (90.0%) and Hispanic (4.2%). As discussed above, one of our goals is to provide a program for underserved children, which we measure of underserved children by the number of children participating in a reduced or free meal program through their school. Figure 9 shows the percentages of children we have served that actually receive free/reduced price meals (48.86%) compared to students that do not (51.14%). Based on the mix of students from a racial and socio-economic standpoint, we feel that we have successfully accomplished the goals of serving children in rural and underserved schools.

Tracking

An ongoing issue with the Robot Roadshow program is the long term tracking to measure to the effect on the children that participate within the program. To have an effective program, there must be verifiable results. With the number of students covered, it is a difficult and time-consuming task to track long-term effects and impact. However, one of the first schools visited, Ogden (K-5), invited us back to present our robotics program during their first ever school science fair. This event took place approximately three months after the Robot Roadshow presentation. Based on this experience, the impact on the children was encouraging, as we witnessed several students presenting and explaining robots to their parents, in technical detail.

Further Work

After a full year of conducting the Robot Roadshow, we have solidified the requirements for long-term success, durability and usefulness. The most prominent is obtaining funding to provide a permanent base for the program and more staff to conduct and deliver the program. This will allow the resources to extend the program to schools farther in distance from Manhattan, Kansas.

We also offer effective publicity for other programs at Kansas State University due to the number of students and faculty with who we are in contact. These programs are generally other K-12 outreach programs from Kansas State University's School of Engineering that serve smaller, more focused groups during summer workshops.

Seeing the ability of small children to logically manipulate robots in simple experiments, we have initiated another program, described in another ASEE paper [11], to build logic and critical thinking skills in children from kindergarten through the 6th grade. It is beneficial to start solving logical problems as the brain is forming in order to develop the required neural plasticity that can be employed over a lifetime of logical thinking and problem solving. This program will reinforce concepts learned during the Robot Roadshow over a long period, accomplishing one of our goals of *Reinforcement.* The program will employ a software-based robotic simulator that allows the student to build a simple sensor/effector robot, use that robot to create a series of logical programming challenges, with increasing levels of difficulty, and evaluate how the robot functions.

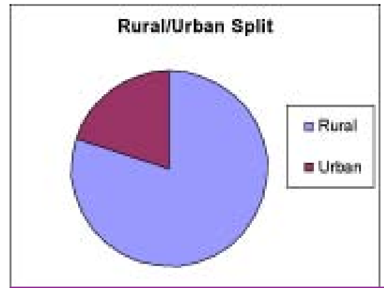

Figure 6: Rural and Urban Distribution

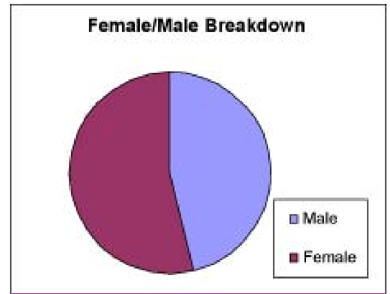

Figure 7: Female and Male

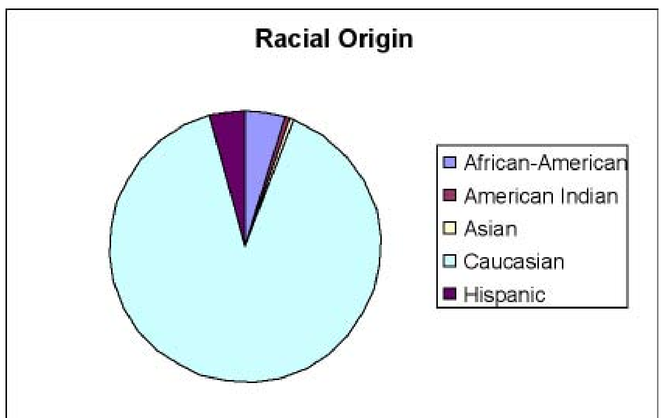

Figure 8: Racial Origin Distribution

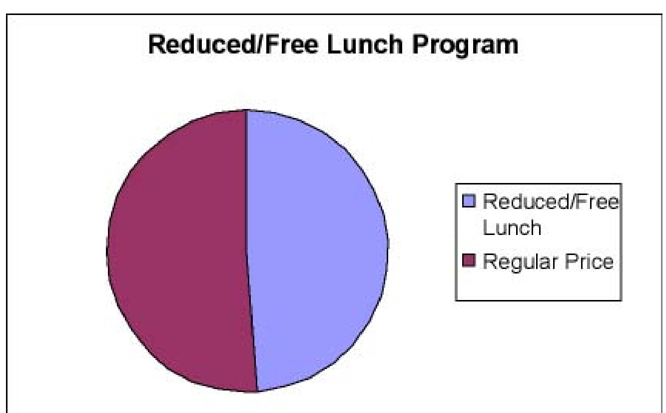

Figure 9: Reduced or Free Lunch Distribution

Another future project is that of a web presence that will provide information to further the discussions and reinforce the lessons of the Robot Roadshow, over a longer period. The idea is to provide a place where all students involved in our program, past and present, can share ideas and designs in a more informal setting.

After the 2002-2003 academic year, the target was set to provide the program for 1000 additional children each semester, which was fulfilled for the 2003-2004 school year.

Conclusion

The goals of the *Robot Roadshow* are to increase the interest of elementary aged students in science, math, and other technical areas. The program includes pre-visit activities to help the students obtain a basic knowledge of robots followed by a multimedia presentation, which includes hands-on experiments with real robots. The program is aimed at rural and underserved communities, which often lack the resources to provide such programs on their own. During its first year, the program was extremely popular with students and teachers with more than 1,200 children participating in the program.

Acknowledgements

The Robot Roadshow Program is funded by the Department of Computing and Information Sciences, College of Engineering at Kansas State University and the National Science Foundation (NSF) under grant IIS-0347545.

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SCOTT DELOACH is currently an Assistant Professor in the Department of Computing and Information Sciences at Kansas State University. His current research interests include autonomous cooperative robotics, design and synthesis of multi-agent systems, and knowledge-based software engineering. Prior to coming to KSU, Dr. DeLoach spent 20 years in the US Air Force, with his last assignment being as an Assistant Professor of Computer Science and Engineering at the Air Force Institute of Technology (AFIT). Dr. DeLoach received his BS in Computer Engineering from Iowa State University in 1982 and his MS and PhD in Computer Engineering from the Air Force Institute of Technology in 1987 and 1996.

ROBYN PAULY is an undergraduate student in Computing and Information Science within the College of Engineering at Kansas State University. She works as an undergraduate research assistant in the Multiagent and Cooperative Robotics Laboratory. Robyn volunteers her time traveling to conduct the Robot Roadshow programs throughout the state of Kansas.

Appendix A

"Robot Roadshow"
Primary School Workbook

The Department of
Computing and Information Sciences
Kansas State University

Eric Matson **Scott DeLoach** **Robyn Pauly**

Multiagent and Cooperative Robotics Lab
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GOAL

Generate interest in math, science, computers and robotics through the use of demonstrations, activities and simple interactive experiments.

ROBOTS

Robots are used in many ways. There are toy robots, robots for science, robots for learning, and robots used in everyday life. Some robots are for indoors, some are for outdoors and others can fly or swim. Robots have even been trained to play soccer!

Robots are built using motors, sensors, wheels, legs, wire, computer chips and many other parts. **Sensors** are the "eyes and ears" of the robots. **Motors** drive the **wheels** or **legs** of a robot to allow it to move. **Wires** inside the robots connect all of the parts together. **Computer chips** are the "brains" of the robot and control the sensors, motors, wheels, legs, and all other parts.

ROBOTS at K-State

At K-State we have robots with names like Pioneer, Amigobot and Scout. We are interested in making robots work together as a team. We experiment with "Search and Rescue" missions to try to find things that are lost. If you got lost, maybe our robots could help find you! Would you like to be found by a robot?

Fun Robot Activities!

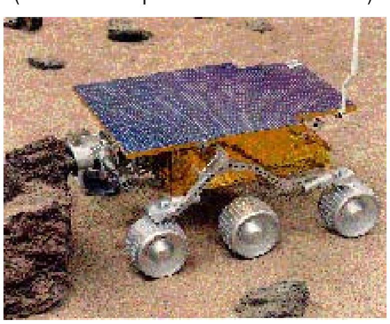
Draw your very own robot! Use your imagination to create the robot. Make sure to label all parts of your robot and describe what your robot does.

Word Jumble

Unscramble these robot related words: *motor, robot, computer, sonar, brain, arms, wheel, sensor*

- putremoc
- tbroo
- naros
- lewhe
- sornes
- smra
- brina
- omotr

A famous robot: Do you know the name of this famous robot? Why is it famous?
(Hint: Look up Mars on the Internet?)



Word Find: Find the following robot words:

- sonar, computer, science, brain, wheels, robots, wires, arms, sensor, motor

S	R	U	W	R	A	N	O	S
C	O	M	P	U	T	E	R	E
I	B	K	L	T	M	J	Q	N
E	O	D	N	B	O	M	O	S
N	T	S	S	N	T	P	S	O
C	S	I	M	X	O	E	W	R
E	R	C	R	X	R	Z	Y	B
C	B	R	A	I	N	G	H	F
A	Y	D	W	H	E	E	L	S

Compare: How are these robots different! Write about the differences!

Hexapod Walker II