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Using Robots to Increase Interest of Technical Disciplines in Rural and Underserved Schools

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Abstract

In Kansas, there are many schools, due to a rural or underserved nature, that fall short in providing access to technical resources to further interest in science education. We have developed a program, using robots, to interest school children in technical disciplines. This program is targeted at schools that do not have people or financial resources to fund a similar program on their own. To make the program interesting, robots are utilized as the vehicle to excite children about science. Our experience indicates that robots are almost universally captivating for children of all ages, in our case, K-12 students.

The Robot Roadshow Program uses a three step process: Pre-visit workbooks, the visit and presentation, and a follow-up session with the faculty to evaluate student impact. The initial step is to send a workbook, consisting of puzzles, short readings, definitions and creative exercises, in advance for each student to complete. There is a different workbook for each of the following age groups: K-3, 4-6, 7-9, 10-12. Tailored by age group, the workbook will develop the appropriate set of skills and knowledge necessary to get the most from the program upon the visit day. On the visit day, several of our robots will go to the school for interactive experiments with the students. Each experiment injects and reinforces principles of science in an interesting, fun and unique way for the students. The faculty follow-up session reviews and evaluates the impact on individual students and the class as a whole. The follow-up review is used to revise and continually improve the program to maximize the impact of the participant experience.

Introduction

When the Kansas territory was first settled, those who went to school often attended a one room school house. The one room school houses were normally short on supplies though provided a reasonable education considering the resources available to them. Although the students were attentive and worked hard toward their academic goals, they were often lacking resources available in larger cities and metropolitan areas. The actual schools were constructed of whatever materials were available and reasonably inexpensive [1]. With the lack of resources to build the very schools, it is easy to imagine the resource deficits that existed, in small schools, when compared to larger 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 better access to information, the fact still remains in smaller towns and school districts that shrinking enrollment, less money and strained resources have put a squeeze on all but the most necessary equipment and subjects. With 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[2]. The Robot Roadshow Program is an attempt to provide an example of a creative method to extend the scientific and math education of these students.

Initial Development

This program got its start from Cub Scout troops interested in robots. The results were so positive we decided to try and extend it as an outreach tool for local schools that wouldn't normally have access to these types of expensive and specific teaching and instructional resources. Contact was made with several schools to determine if the proposed program would be a viable and welcome augmentation to the normal science and math curriculum. The response was positive in all cases. At this point, the program outline was developed and the initial pilot program was tested on two classes of 2nd graders at a small area school in Manhattan, Kansas. After completion of the pilot, a follow up was conducted with the two 2nd grade teachers to determine the program's value and any changes to add additional value or impact.

Program Goals

Our goals for this program are very simple:
1. Create opportunity for underserved/rural schools to have access to additional learning resources.
2. Allow the students to enjoy math and science.
3. Allow students to build a relationship between the study of math and science and interesting subjects (robots).
4. Create process to reinforce the experience, so that after the visit the child's interest doesn't deteriorate.

School Selection Criteria

This program was founded with the idea of extending and augmenting the education provided by rural or underserved K-12 schools in math and science. Due to of the sheer number of school districts in the state of Kansas and the limited resources available to execute this program, we developed a criteria to determine if a school is defined as rural or underserved. After a school has been determined as meeting the criteria for one of those categories, we prioritize requests in order of need and economic feasibility. Need is based upon a review of their program application. Economic feasibility consists of the cost to travel to put on the program measured against the number of students and targeted audience. In case there are more requests than we can fulfill, we will use the priority to determine where to present the program.

School districts with large science and technology budgets are not the target of this program. The targeted school districts typically represent a population base of 8,000 or less. This makes up a great percentage of the Kansas school districts. School districts, in this category, normally are rural in scope and typically have less opportunity to go beyond the basic resources provided by the curriculum. A more difficult category to define is that of underserved schools. For our program, we define an underserved school as one that has fallen behind based on math and science scores regardless of the size or population base served.

Process

The approach of our 3 step process is to build a base of knowledge and interest via the Pre-visit Workbooks we provide, then reinforce and strengthen that learning experience with the Visit Day lessons, activities and experiments. These activities are followed up by the review with the sponsoring teacher at the selected school, so that we can continually improve our program and the delivery process, as shown in Figure 1. Due to the short nature of our experience with the program, we anticipate that we will change and improve it continuously, in order to provide the most effective and efficient learning experience possible for the target schools.

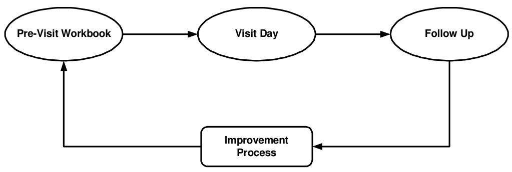

Figure 1: Delivery Process

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[3]. The reward or outcome is to see an interesting presentation and 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. The difficulty of the Pre-visit Workbook and the technical expertise required for the experiments is adjusted for each age group.

<u>Pre-visit Workbooks</u>

The goal of the Pre-visit Workbook is to develop a basic understanding of the program, use games and puzzles to learn about robots, and provide an independent exercise appropriate to prepare for the Visit Day. An example of the pre-visit workbook for elementary school is displayed in Appendix A.

Visit Day

The visit day program normally lasts about one hour per group of children. There is a set agenda followed to deliver the program leading the students from an introduction to the robots via a logical progression with the students actually working "virtually hands-on" with the robots conducting 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 of robotics. The capstone experience is a set of experiments to allow the children to have a sensory experience with the robots. The agenda is identical for all ages with the exception that the high school students are the only group to participate in the Multi-agent Race experiment.

In the lecture, we discuss human and robot intelligence, then progress into learning and finish with sensors. In each phase we compare and contrast the way 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, a 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 direction to run from one side of a room and exit the doorway of the room. We give that direction, velocity and acceleration are the same between the robot and the human. 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 human 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. The human will win not because of functionality, but because of 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 sensor types, or senses, allows us to learn almost continuously from our environment. We discuss the nature of each sensor and how our brains can automatically switch from using one sensor as a primary sensory, 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 or kitchen. The first task is to locate the light switch. We ask the children what sensor is appropriate for this usage. Most say the sense of touch as they will need to reach out blindly to find the wall, even though they know the mental map of the room. Once the light is switched on the sense of touch is no longer the primary sensor and vision is used to navigate. We then tie this use of sensors into what 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

The movie shown visually describes a potential Mars exploration project using biologically inspired robots, from the field of biomimetics. The *Entomoptor* movie[4] shows a space craft flying through space, moving into Mars orbit and landing on the Mars surface. After a successful landing, a team or robots unfolds 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 rover robots and they are accompanied by robots that appear similar to butterflies or birds with wings that explore the surface with greater speed and ability. The movie is entertaining and builds a linkage to how interesting technology can be and also what is possible.

The set of experiments and games executed during the program is meant to engage the students in an active learning engagement instead of a passive lecture. We find the interest is much higher with this format. We have worked through several designs of these experiments to evolve the current set. The experiments and games employed are Robots Roaming, Escape the Circle, Robot Race and the Multi-agent Race.

In the *Robot Roaming* experiment, shown in Fig. 3, we build a bridge between 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.

Figure 3: Robot Roaming

The goal of the *Escape the Circle,* in Fig. 4, experiment is to show the student the difficulty an uninformed robot has at doing even the simplest of tasks, in this case, rolling out of a small circle. We can compare the ease a human can escape the circle to draw a comparison between human and robot intelligence.

Figure 4: Escape the Circle

The *Robot Race*, shown in Fig. 5, is an extension of the Escape the Circle. In this experiment, the children are split into two teams each having a robot assigned to them. Both robots are started as far away from the opening in the circle of children as possible. The goal is to see which robot can escape first. That team is declared the winner. Normally this experiment is repeated multiple times to show that there is no advantage from one robot to the next.

Figure 5: Robot Race

The *Multiagent 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 and 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 humans. Each iteration yields a discussion to determine if adding a new person was a help or a hindrance to 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.

Post Visit Evaluation

The goal of the Post Visit Evaluation is to benefit from the teacher's perspective on ideas to improve the program. We want their direct input on how helpful and appropriate the Pre-visit Workbooks were, the Visit Day experiments, game and presentation and also any other follow up or customization that may have been developed for their particular visit.

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 2 hour drive from Manhattan, Kansas. Of the 1,215 students they were split between 243 children from urban schools and 972 children 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.

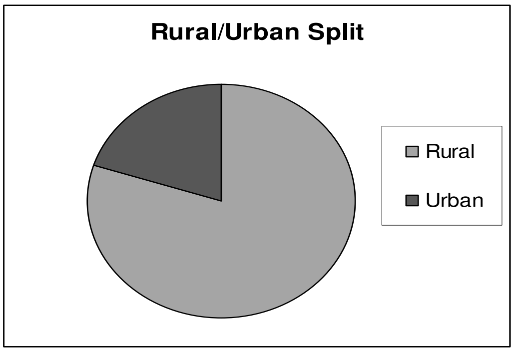

Figure 6: Rural and Urban Distribution

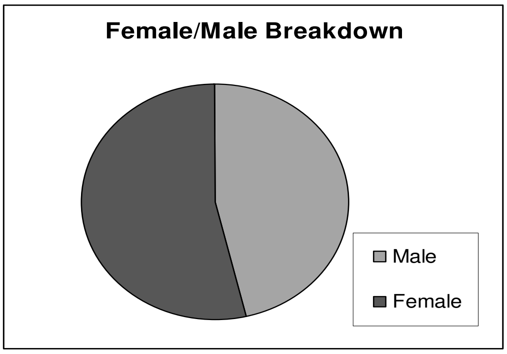

Figure 7: Female and Male Distribution

In Figure 8, we describe the racial origins of the participants. Representatives of five groups participated in the program: African-American (4.7%), American Indian (.5%), Asian (.6%), Caucasian (90.0%) and Hispanic (4.2%). An aim is to provide a program for under served children. The measure of underserved children, by our standards, is from the number of children that participate in a reduced or free meal program through their school. In Figure 9, the percentages of children that receive free/reduced price meals (48.86%) compared to students that don't qualify (51.14%).

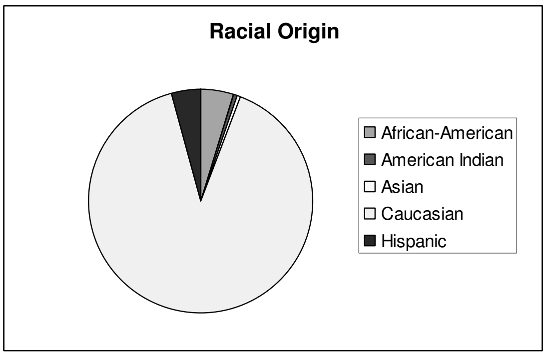

Figure 8: Racial Origin Distribution

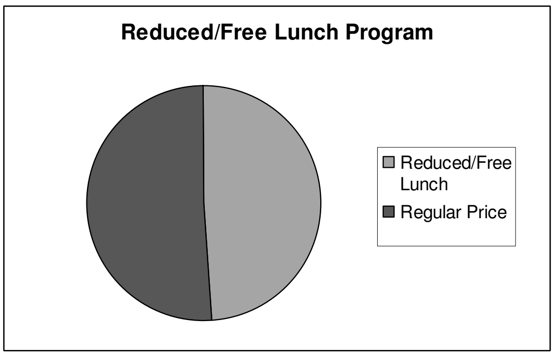

Figure 9: Reduced or Free Lunch Distribution

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 under served 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.

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 3 months after our *Robot Roadshow* presentation. The impact, on the children, was encouraging as we had children presenting and explaining the function of the robots to their parents, in technical detail, with no advance technical preparation.

Further Work

After a full year of conducting this program, we have solidified the requirements for long term success, durability and usefulness. The most salient plan element is the gain of 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 have developed links to other programs that we can serve via the publicity and general number of students and faculty we are in contact with. These programs are generally other K-12 outreach programs from Kansas State University's School of Engineering that serve small constituent groups during summer.

In reviewing the ability of small children to logically manipulate robots in simple experiments, we have begun another program, described in another paper[5], to build logic and critical thinking skills in children from kindergarten through the 6^{th} grade. This program will reinforce concepts learned during the Robot Roadshow over a long period of time, accomplishing one of our goals of *Reinforcement.*

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 of time. 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.

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Biographical Information

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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.