InnoWorks 2004: RoboVentions

The Impact of Hands-On College Student Mentoring on the Attitudes and Skills of Unprivileged Middle School Students in Science and Engineering

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I. Purpose and Motivation

For many underprivileged students, exposure to science and technology is limited to the theoretical concepts taught in school. This narrow experience is compounded by the common youthful sentiment that science is not stimulating. In middle school and early high school science classes, the concentration is often on producing building blocks for increasingly complicated future topics. The response to the question, "What does this have to do with anything?" or "Why should I care about this?" is too often followed by the response, "You'll understand when you learn more later." In the absence of interesting science related experiences, many students never pursue their nascent interests.

The vision of **InnoWorks**[1] is to design and implement innovative workshops in science and engineering for underprivileged students to meet the following goals: (1) To provide students without easy access to extracurricular science and engineering programs with an opportunity to explore the links between the classroom and the real world, (2) To foster lasting collaborative skills and the development of strong work ethics, (3) To develop interpersonal relationships in a community-focused mentoring environment, and (4) To encourage science and engineering as potential career paths.

The InnoWorks target group is underprivileged middle school students because youth are most impressionable at this age. Moreover, disadvantaged students may find themselves in environments that lack role models.

[1] InnoWorks is a program of the ***United InnoWorks Academy, Inc.***, a non-profit, educational-based 501(c)(3) organization dedicated to nurturing future leaders. InnoWorks is organized, managed, and operated by volunteer college students from around the country.

II. Background

There seems to be a strong focus in the United States educational system on teaching to tests to present a facade of student achievement rather than stimulating positive attitudes towards academics. Forcing students who fail in particular subjects or tests to repeat the same ordeals has little chance of helping them towards a lifelong desire to learn. John Ferrandino, President of the National Academy Foundation, argues that with extra testing "[y]ou're going to end up with kids who are very good test-takers, to the exclusion of a great many other things that need to be taught in schools" (Jost, 2001). Paralleling what is often the focus in schools, extracurricular programs are increasingly centered on test preparation rather than promoting interest towards learning or nurturing collaboration in solving real-world problems.

An arguably better but more challenging approach is to fundamentally transform attitudes towards greater reception to learning. InnoWorks' first thesis is that disadvantaged youth stand to benefit significantly in the short- and long-term from mentoring programs that expose them to realistic, creative hands-on learning. A study done by researchers at the University of Missouri supports this approach: "the strongest empirical basis exists for utilizing mentoring as a preventive intervention with youth whose backgrounds include significant conditions of environmental risk and disadvantage" (Cooper, 2002).

Youth are full of imagination and enthusiasm, although these characteristics are not always channeled towards productive ends. InnoWorks hopes to direct their creative energy towards positively impacting the greater community. One researcher came to this conclusion:

> *Active participation of youth is essential to reenergizing and sustaining the civic spirit of communities. Through skill development in the areas of collaboration and*

leadership, and the application of these capacities to meaningful roles in community, youth can play a fundamental role in addressing the social issues that are destined to impact their lives and those of future generations (Hancock, 1994).

The second thesis of InnoWorks is that how the mentoring is delivered is critical to obtaining the desired impact on these young students. With the close proximity in age and relatively similar experiences, InnoWorks believes that college-age mentors knowledgeable and passionate in science and technology are ideal role models to provide these students with positive influences through and beyond the program.

III. Program Structure

In order to create an effective program, we recognized the need to have a well-structured agenda. As Burrell et al. explain, effective mentorship involves five processes:

1. *An intentional process*
2. *A nurturing process*
3. *An insightful process*
4. *A protective and supportive process*
5. *A role modeling process*

For the first point, our program is a reflection of our intent to have a positive impact on these underprivileged youth. For the second process, the mentors worked closely with the students and helped spark and maintain their motivation while guiding them towards success. For the third characteristic, it was our mission for the students to acquire and develop independent and team-building skills during the program. For the fourth principle, the mentors encouraged cooperation and friendly competition by supporting his/her team and thereby gave the students a sense of collective identity and team spirit. For the fifth and last point, the mentors conducted themselves as role models through their words and actions and sought to advise the youth and answer their questions.

Burrell et al. suggest that these processes "involve investments of thought, time, and effort that elicit a vast mixture of developments and changes that allow people to continue to expand their capabilities… Purpose, creativity, and personal investment are critical elements for effective mentoring relationships. Participants need a clear vision in conjunction with a structured mentoring program." (Burrell et al., 2001).

The InnoWorks program was developed with these guidelines in mind. The purpose of the inaugural 2004 program[2] was to design a one-week interactive workshop that achieved the goals of InnoWorks and tested the two foundational theses. The program this year was entitled **RoboVentions,** short for "Robotic Inventions". Robotics was the underlying theme used to explore a number of scientific and technological disciplines. The 2004 workshop was implemented in collaboration with many groups and hosted by the Montgomery County Department of Recreation.[3] The workshop was held at the Scotland Community Center in Potomac, Maryland from August 16-20, 2004. The RoboVentions program was provided to the students free of charge[4].

IV. Program Description

The 2004 RoboVentions staff and mentoring group consisted of seventeen motivated college students majoring in science, engineering, and other related disciplines who are passionate about helping others and for sharing their interests and knowledge.[5] Eight mentors each worked with a project team of four or five students throughout the weeklong workshop.

Students between the ages of 10-17 were nominated based on their disadvantaged status and their demonstrated interest in hands-on, cooperative learning. The Scotland Community Center selected over ten students while other students were nominated by guidance counselors, principals, and teachers at local middle schools in the greater DC metropolitan area. Students registered either via phone contact or with an online form. A total of thirty-four students attended—26 boys and 8 girls.

Figure 1. (Left) Sheyi Ayeni (Stanford, '06) and his team take a break to pose for the camera. **(Right)** Daniel Kaplan (Pratt, '06) and Nancy Ku (Rice, '06) talk to their teams before the activities begin for the day.

Each project team built simple yet dynamic robotics using the versatile LEGO™ Mindstorms Robotics Kits. While the central focus was robotics, specific missions were highly interdisciplinary, delving into other areas of

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[2] The 2004 InnoWorks Program was partially supported by a President's Research Fellowship Grant from Duke University and sponsored by Dr. Gary Ybarra, Professor and Director of Undergraduate Studies for the Department of Electrical and Computer Engineering. The full list of sponsors is listed in Section IX.

[3] Montgomery County, Maryland.

[4] www.innoworks.org

[5] Schools represented: Brandeis University, Carnegie Mellon University, Duke University, Northwestern University, Rice University, Stanford University, and the University of Maryland College Park.

science, engineering, and even economics. We tried to provide a creative and innovative environment through cooperation and friendly competition. Specific disciplines covered included engineering, microbiology, computer science, conservation biology, ecology, economics, financial and resource management, and psychology.

Each team was provided with a worktable, a PC computer with all necessary software preloaded, and a LEGO™ Mindstorms Robotics Invention System Kit. Completion of different aspects of the assigned missions earned teams points, which could be spent to purchase extra parts from the *Robostore*. This economics component was added to help the students understand resource scarcity and the importance of efficiency. Many engaging student debates were observed over the relative merits of spending points to improve their designs versus conserving points. Extra points were awarded for creativity, efficiency, aesthetics, and teamwork. The goal for each team was to earn as many points as possible. Awards were given to all participants, with the higher finishing teams winning larger trophies.

An hour and a half in the middle of each day was allotted for lunch, which was provided free for the students, largely to keep them on site to interact with the mentors, staff and other students in a more social setting. Team building activities with mentors and students participating together were planned for each day, with at least one active and one sedentary activity offered, including games such as capture the flag, basketball, board games, and arts & crafts.

All teams were led through a training mission on the first day (Figure 2) to give every student the fundamental robotics knowledge for the rest of the week. With this learning phase prior to the competition, students were more comfortable proceeding to the mission challenges.

Figure 2. (Left) Matt Mian (Pratt, ’06) oversees his group constructing a robot that can maneuver past obstacles for the training mission. **(Right)** Amanda Way (Trinity, ’07) and William Hwang (Pratt, ’06) try and resolve chronic computer problems for this group.

To emphasize the interdisciplinary nature of real-world problem solving, each mission was preceded by interactive presentations that provided a context for the subsequent projects. In order to stress the importance of the design phase in the projects, all teams spent thirty minutes in quiet, isolated areas without access to any equipment to brainstorm and discuss ideas. This allowed the students to discuss the relative merits and drawbacks of different designs and collectively develop an optimal solution. The emphasis was on intellectual equality and openness to everyone’s ideas.

Ecology and recycling were the topics of the first presentation and mission; the students acted out skits depicting different aspects of the recycling process for paper and glass, took an online survey that evaluated their impact on the environment, and learned how to make recycled paper from newspaper. The mission associated with these topics was to design and build a robot that could sort blocks of different colors (designated trash and recyclables) into different bins (Figure 3).

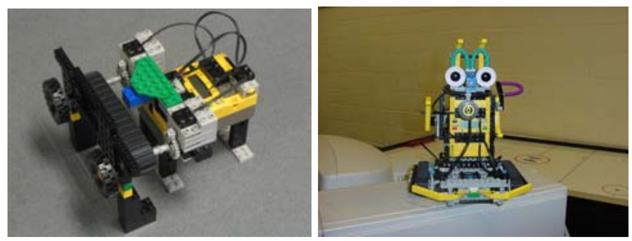

Figure 3. (Left) Brick sorter design that earned the “Most Efficient” design award. **(Right)** Basketball playing robot.

The second presentation/mission was centered on bioluminescence, photo- and chemotaxis, and psychology. Students watched a clip from *Finding Nemo* and learned to mimic primitive forms of taxis. The associated mission was a rover that could navigate along a course by following a painted path while avoiding obstacles (Figure 4), search for lights (small pen lights) in the environment, and issue an emotionally-based response upon finding the light. This last psychological component was incorporated to get the students to think about the requisite mechanistic behaviors for different emotions and how to convey different feelings through the simple movement and sound capabilities of the robots.

Figure 4. (Left) Jessica Manson (Pratt, ’06) and her group working together to construct the body of their robot. **(Right)** Robert Day (CMU, ’06) making some calibration measurements on the testing apparatus for the pathfinder mission.

The third and final mission involved sports and biomechanics. Students were asked to build robots that could play basketball. Major considerations for this project were accurate alignment of the robot to the basket and the design of a sensor-triggered arm to shoot a ping-pong ball into the basket (Figure 3).

Family members were invited to join the program for an open house on the fifth and last day of the RoboVentions 2004. Parents and guardians watched and cheered on their children's competition entries, and were present to congratulate the students during the award ceremony. As an incentive and reward for their hard work, all students received InnoWorks T-shirts and trophies for completing the program (Figure 5). Local merchants donated an assortment of coupons that were also given to the participants. Larger trophies were presented to the top three finishing teams, and twelve individual trophies were given for two males and two females in each of the following categories: *Most Valuable RoboVentor* (a student who contributed most in helping his or her team succeed), *Most Improved RoboVentor* (a student who showed dramatic improvements in attitude and/or skills through the course of the week), and *Most Dedicated RoboVentor* (a true team player who worked hard and did whatever it took to help his or her team).

Figure 5. (Left) The winning team proudly displaying their trophies and robot. **(Right)** William Hwang (Pratt, '06) and Michael Li (UMCP, '06) thank our partners and sponsors and give out awards.

V. Impact Evaluation

The InnoWorks program is novel in its goals of introducing unprivileged students to a world with role models which may otherwise be few and far between. Although we hoped to teach students specific skills in science and engineering, our main impact potential was in improving the participants' attitudes toward science and technology so that they will be motivated to embark on further exploration of these fascinating disciplines.

There has been a great deal of research on a wide variety of community service projects, including mentorship programs. However, there is scant material on our specific type of program. To investigate the impact of our intervention on the youth, we created comprehensive pre-workshop and post-workshop surveys intended to discover their ambitions, career objectives, work ethics and views on science and engineering, and how they may have changed as a result of the program.

There were also implicit evaluations of skill development throughout the program. The dynamics between the students and between the mentors and students were carefully documented.

VI. Analysis of Student Feedback

On the first day, the students were asked to fill out a pre-survey with a variety of questions ranging from their interests in and out of school to what they might want to pursue as a career. At the end of the program, students completed post-survey questions similar to those on the pre-survey, allowing for comparison.

One question was "How interesting do you find the science taught in school?" The statistics show some trends that we expected, namely that the disadvantaged students were less interested in science than their wealthier peers. Initially, Whites gave an average score of 3.4, Asians gave an average score of 3.5, and Blacks gave an average score of 3.0, where "1" denotes no interest at all and "5" denotes maximal interest (Figure 6). The average interest in science was 3.3 on the pre-surveys and 3.6 on the post-surveys, showing a slight increase in science interest-levels from the beginning of the week to the end of the week.

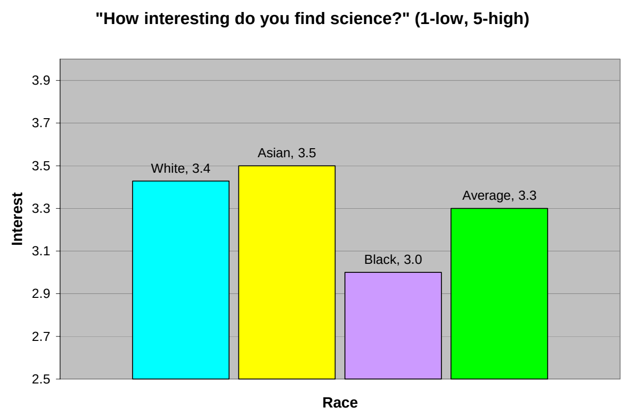

Figure 6. Average interest in science by race on pre-surveys. A response of "1" indicated no interest and a response of "5" conveyed maximal interest.

When initially asked "How important do you think science will be in your future job?", the response was essentially the same for all races. Whites gave an average score of 2.9, Asians gave an average score of 3.1, and Blacks gave an average score of 3.0. A score of "1" indicated that the student believed science would be of minimal importance in his or her future career, while a score of "5" indicated necessity. The average usefulness of science was 3.0 on the pre-surveys and 3.2 on the post-surveys, demonstrating a small increase in the students' perception of the usefulness of science during the course of the week.

Some of the free response questions yielded interesting results. For instance, when we initially asked the students what the worst part about science was, one student wrote that "[t]he worst part about science is science." The most common dislikes about science class tended to revolve around test-taking and note-taking/listening to lectures, while the most common positives about science class related to its future utility, which indicated that most students at this age (primarily 12 and 13 year-olds) understand that education pays off in the long run.

Over 94% of the students responded that they enjoyed the program, would come again to a similar camp, and would recommend a friend to come as well.[6] When we asked for miscellaneous feedback, three students indicated that they wanted the program to be longer.

We also asked students for their input on improvements for the program. The only major area that many students complained about was the length of the daily presentations, which they felt were too long. We predicted that we would need to constantly change the pace of activities because of their short attention spans, so we tried to break down the activities into smaller segments. However, their feedback suggests that this is an aspect that should be reevaluated.

One student wrote two special letters to us at the end of the program to express her feelings regarding InnoWorks: "'InnoWorks' was *amazing*…thanks again for all of your effort and commitment towards making this class educational and fun (and rarely do those two words go together)". We also received letters of appreciation from the Director of the Montgomery County Department of Recreation and the Director of the Scotland Community Center.

VII. Analysis of Mentor Feedback

Following the completion of each day's events, the mentors each filled out a survey to reflect on the progress of their students. These mentor evaluations served as a valuable tool in appraising both our impact on the students and the means by which we were achieving that impact.

One interesting development was the establishment of hierarchies within the individual groups. Some students were observed to dominate while others chose to follow. Although this may have been expected, it was interesting to trace the characteristics of the dominant students over time. Initially, the dominant students were loud, aggressive, and outgoing. Throughout the week, however, these same students began to lose influence if they could not demonstrate commitment to the team. By the end of the program, a completely new set of students had assumed control within the groups. The new team leaders were generally creative, cooperative, and dedicated to the success of the team as a whole.

We also observed that students frequently used outside knowledge of science to tackle new robotics challenges. This was consistent with one of the goals of InnoWorks—to bridge the gap between the theoretical constructs of science and problems faced in the real world. As we had hoped, participants often used the context of their conventional science educations to explore a new field—robotics. Students most notably used their outside experience in the design of their robots and in their approach to programming them.

In summary, the mentor surveys provided a wealth of information on teaching styles, student behavior, and program structure. The surveys have given rise to a list of recommendations we hope to incorporate into future programs. Concepts such as teamwork, feasibility of design, and presentation of results will be stressed in future programs.

VIII. Future Directions

We plan on improving upon the successes of InnoWorks 2004 in the upcoming year and expanding the program to several national chapters: Carnegie Mellon University, Duke University, Indiana University, and University of Maryland College Park. At Duke, we are currently in the process of obtaining a charter to become an officially recognized organization under the Community Service Center. This will facilitate the expansion of the program and the development of a continued base of operation for the future.

We have recruited a team of outstanding students from different departments at Duke with strong interests in education and helping underprivileged youth. The program will most likely be held on the Duke campus in the summer of 2005 with nominated students for the program bused to campus from the Durham area. Rather than focusing on full-length projects (i.e. design conception through final testing), we would like to more fully realize our vision of "Innovative Workshops" by exposing the students to many more disciplines. We currently have committees in Earth Science, Physics, Psychology, Neurobiology, Chemistry, Engineering, Computer Science, Ecology, and Biology. While we have structured the committees into distinct disciplines, we will divide the days into themes instead of subjects to deemphasize association of the program with school and to stress interdisciplinary interactions. For example, a potential theme could be "The Human Senses", for which one mission may be to measure the speed of sound (hearing, Physics) and another could be a series of optical illusions that need to be explained (sight, Neurobiology/Psychology).

The program will have three different types of activities: (1) team-building activities to develop friendships and trust in each other, (2) interactive presentations and activities (non-competitive) for learning, and (3) fast-paced, competitive missions and student presentations to develop teamwork, problem

[6] Many kids did in fact try and bring friends during the week, many of whom, unfortunately, we could not accommodate.

solving, laboratory, and communication skills. Type (1) activities will be held during the first day of the program while type (2) activities will generally be in the morning and type (3) activities will be in the afternoon.

To have the youth develop valuable communication and presentation skills, one team will be randomly selected each day for each project to give a five-minute presentation on their solution to a mission. This will also serve as a nice capstone for each project.

During the school year following the program, we will continue to keep in contact with the students by two primary methods: (1) organized events (e.g. interesting science and engineering competitions and/or presentations) that will most likely be held on campus, and (2) a web forum through which students can communicate with their mentors and other staff members, allowing the students to ask us questions whenever they need advice/help in academics or otherwise, and at the same time provide us with a good method to continue monitoring the areas of impact InnoWorks had or did not have for the students, and to continuously assess how to improve the program to better meet our goals.

The development of InnoWorks 2005 is ongoing. More information can be found at *www.innoworks.org*.

IX. Acknowledgements

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