AC 2007-6: ENGINEERING: BEYOND EARS IN PRE-COLLEGE YEARS

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Abstract

A 12-week program was developed in which electrical engineering concepts, in form of robotics projects, are taught to students at a secondary educational institution for the deaf and hearing impaired. The robotics course was originally designed for, and has been taught for about a decade to freshmen at the Temple University college of Engineering. The objectives of this project range from eliminating existing boundaries of engineering education to increasing the anticipation of success amongst the physically impaired. A prior breakthrough in the extension of engineering education beyond assumed "limits" was achieved when a young man who was both sight and hearing impaired earned a bachelors degree with honors from the Electrical Engineering department at Temple University. Since then, several outreach programs have been run to increase engineering awareness in the community, and this project was carried out with the same perspective in mind. In this paper, an overview of the idea of engineering education for hearing impaired pre-college students will be given. The goals of the program will also be described in detail, and didactic strategies, pedagogical considerations and empirical observations will be presented. This program, which has been run once at the Pennsylvania school for the deaf, was evaluated based on responses of the students and their science teacher. Results of the evaluation procedure will be analyzed in this paper.

1. Introduction

During the past decade, organizations such as the National Science Foundation and the American Society of Engineering Education have put in a lot of effort in taking engineering beyond college walls to students in pre-college institutions[1]. These efforts came about as a result of observations that many young scholars in the United States are usually detached from engineering related courses before they get an opportunity to be formally educated in such subjects. In Temple University, High school students are reached out to through a summer robotics program run by the ex-chair of the Electrical Engineering Department, Dr. John Helferty. 80% of Participants in this program have gone on to study engineering in college, and about 40% have been known to graduate with an engineering degree. An impact was also made in engineering for the disabled when Temple University graduated the first ever blind-deaf engineering student (Scott Stoffel). He not only performed outstandingly throughout his academic career, but also created several senior design projects opportunities for successive electrical engineering seniors after him through his own project which involved creating a system which made it easier for blind-deaf students with low sensitivity, like himself, to communicate.[2,3,4] The achievements of Scott Stoffel motivated an outreach program, which involved teaching the concept of electrical engineering through a series of courses in robotics to high school freshmen at the Pennsylvania School for the Deaf (PSD). The main objectives of this program were as follows:

1. To increase engineering awareness and encourage the desire for engineering education amongst high-school students who are deaf or hearing impaired.
2. To present engineering in a method that is suitable for pre-college students who are deaf or hearing impaired.
3. To give deaf students a sense of self-confidence and anticipation of success amidst the vast rate of technological advancement in today's world.

4. To demonstrate to the students that communication for them is not limited to those who understand sign language and know how to sign, and to the hearing, that communication goes beyond speech.
5. To make a statement, to all, that everyone can learn engineering – it is a thing of the mind!!

The robotics courses were taught by two electrical engineering doctoral students, by the help of an interpreter and the high school science teacher at PSD. The strategies employed in attaining the above mentioned goals are presented in this paper, as well as some of the challenges faced and how they were overcome. The aim of this paper is to present some useful tactics for tackling difficulties encountered when teaching technological subjects in non-traditional teaching environments. This paper is organized as follows: In Section 2, the art of teaching science to the deaf is discussed, and the challenges encountered in the process are addressed. The concept of introducing the subject of engineering to pre-college students is analyzed in Section 3. In Section 4, the PSD robotics program, which was a combination of the topics presented in Sections 2 and 3, is explained in detail along with the strategies, considerations and challenges faced. The evaluation procedure performed for this program is presented in Section 5, as well as the results obtained from the process. Finally, conclusions are drawn in Section 6 based on inferences made from the evaluation results.

2. Teaching Science to the Deaf

Presentation of scientific concepts to students who are deaf or hearing impaired needs to be carried out with caution because, in spite of the popular saying that "people who are deaf can do everything hearing people can do, except hear", research has demonstrated that viewing deaf learners simply as students who cannot hear could be detrimental to their learning process.[5] In general, deaf students have very different learning styles and cognitive behaviors; for instance, they are known to learn and retain knowledge mainly through visualization.[6] Therefore, the curricula structures in deaf classrooms needs to modified from those of hearing classrooms, so as to meet any special requirements that might enhance their education, especially with regards to science related subjects, which are usually more complex in terms of vocabulary and reasoning. Consequently, numerous research efforts have been made in developing approaches and strategies by which science can be successfully taught to deaf students[6,7,8,9,10].

Implementation of effective instructional development strategies for deaf education in Science not only improves their learning abilities, but also ignites or increases interest in science-related subjects amongst deaf or hearing impaired students. Previously, over 30 research investigations were performed on science education for deaf students, which revealed, in essence, that teaching strategies which encourage intellectual reasoning among deaf students yield the most desirable results[11]. Some approaches that have been suggested by renowned researchers of deaf education for efficacious instruction of deaf students are as follows:

- *Qualification of teachers:* Several science teachers in public (including deaf) institutions have been reported to be under-qualified for their profession or depraved of necessary support for professional growth.[12] This inadequacy has adverse effects on the learning ability of their students; for instance, some teachers turn their lessons into lectures when they do not have full control of the subject matter. [6] It has been observed that science students who are deaf have the same capability as hearing students to decipher when a teacher does not have sufficient knowledge of the subject matter he is presenting to students, or lacks the necessary training required to explain the material clearly.[6] When students make such observations, they usually become less attentive and tend to lose interest in the subject relatively faster. This, in addition to the poor teaching quality, usually results in poor performances from students especially in standardized examinations.[13] It should therefore be made mandatory for science teachers in deaf institutions to have acquired the necessary credential before being allowed to teach. Teachers should also ensure that they are constantly well-prepared before each class, as this will increase classroom interactivity between students and teachers. Science teachers also need to be encouraged and supported to attend professional development conferences and seminars in order to enhance career growth and ensure that they are continually equipped for the rapidly advancing technology.

- *Multimedia:* Visualization is a major requirement in deaf learning, as students who are deaf or hearing impaired are normally very alert in sight. The use of visual aids such as power-point presentations and videos should be promoted in classrooms. Science education involves a lot of complex vocabulary which could be new to students, and therefore difficult to grasp; moreover, students often get bored when they find it difficult to relate to the lesson. Thus, presenting illustrations of topics being introduced would be beneficial in impressing knowledge upon students.
- *Learning structures*: previous research revealed that most high school students (both deaf and hearing) depend on authorities for direction.[14,15] Since deaf students are visual learners, the use of organization tools such as tables, charts and maps could be useful, as it makes it easier for them to comprehend the material. Active learning also plays a key role in science education. Studies have shown that students do not easily get rid of initial conceptions even after they have been taught scientifically correct facts about the same subjects. However, this problem could be addressed by involving such students in activities that force them to knowingly eradicate such misconception, while absorbing the correct knowledge.[10] This is where active learning comes into picture, because, as students are made to participate in their own learning experience through group discussions, presentations of their own understanding, practical experiments, they gradually come to terms with the lesson, and their initial misunderstandings are revised or replaced with more formally correct reasoning. It has also been observed that deaf learners respond better to mind-based activities than to hands-on activities that require little or no logical reasoning. [6] Alternating between individual and team projects or activities can be beneficial to deaf learners, as they are given opportunities to progress at their own paces, and also taught to accommodate others. In order to boost self-confidence in students, motivational activities should also be included in the classroom structure. Rewarded competitions should be encouraged in classrooms, as this could ignite a determination to succeed and also increase the observational learning experience of the students [6].
- *Extra-curricula activities*: Increasing students' participation in science activities outside the classroom helps develop and maintain their interest in the subject. Such activities include science clubs, excursions to science based institutions such as hospitals, factories and zoos, partnership research (for exceptional students) and science publications or presentations. Furthermore, students could be encouraged to participate in science fairs, along with their hearing peers, as this could boost their self esteem and persuade them to perform well.

3. Introducing Engineering to Pre-College Students

The high school robotics summer program held at Temple University is only one of several efforts being made by institutions and the Federal government to enhance engineering awareness amongst pre-college adolescents. Participants are normally 9^{th} to 12^{th} graders from high schools in and around Philadelphia, who have been observed by their teachers to possess characteristics that might make them inclined towards engineering. This course introduces to the students some basic concepts of electrical and computer engineering in addition to the extensive laboratory experience gained while they assemble and program autonomous robots. At the end of the program, participants are expected to have a background in topics such as resistive-capacitive circuits, diodes, transistors, operational amplifiers and timer circuits, programmable microcontroller interfacing, photoresistors, infrared sensors, and transmitters. Grading for the course is mainly based on their ability to navigate their robots through a course, shown in Figure 1 below, which is similar to navigation courses used in nation-wide robotics competitions. Students who successfully complete the program are given college credits towards and engineering degree, and some of then also take part in the FIRST Robotics Competitions (www.usfirst.org) with support form Temple University.

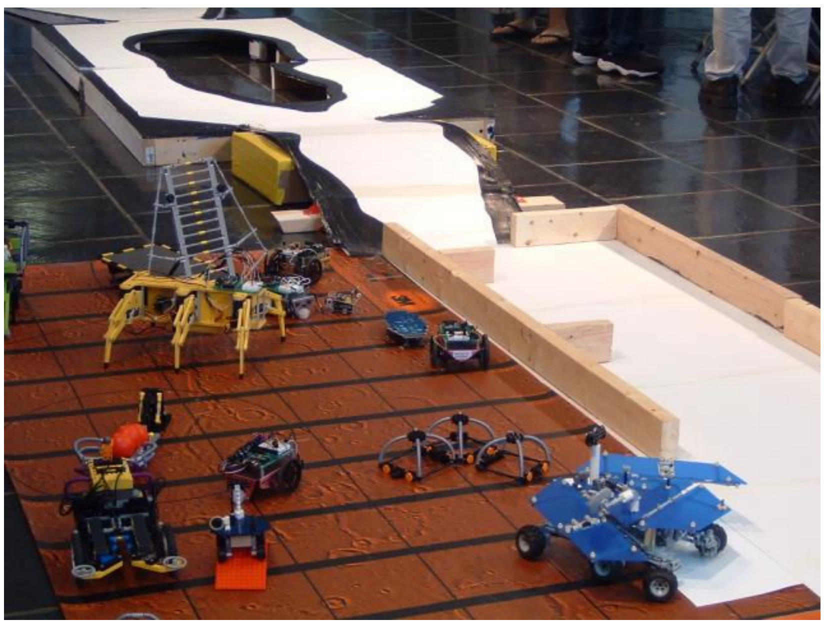

Figure 1: Navigation Course to be completed by autonomous robots programmed by high school students participating in Temple University’s engineering outreach program.

The basic aim of programs such as this is to increase the number of students who enroll in engineering programs, which has always been a concern for engineering faculty nationwide.[1] While post secondary organizations and federal agencies constantly make efforts to this end, some responsibility must be taken on the part of secondary organization to provide students with engineering backgrounds or ensure that the engineering knowledge they may have acquired elsewhere is maintained. Some useful practices that could be adopted in high schools include:

- Incorporating the subject of engineering in the school curricula in addition to basic science courses.
- Providing teachers with special training for teaching engineering.

- Involving students in external engineering projects or competitions such as Engineering (not just science) fair and the FIRST Robotics competition.
- Organizing occasional seminars where engineering researchers or those in the industry present their work to students.
- Supporting talented students, financially, who are interested in participating in engineering programs run by external institutions.

4. Robotics Program at the Pennsylvania School or the Deaf

The robotics outreach program was a 12-week long program which replaced a section of the physics curriculum for ninth graders at PSD. Participants of the program included 9 students, the high school science teacher, the technical aide, an interpreter (since the instructors were hearing and could not sign) and the 2 doctoral students who taught the course and an interpreter. Classes were held for 2 hours in a smart classroom which included a smart board and 5 personal computers. The course outline, pedagogical considerations, didactic strategies and challenges faced during the program are discussed below.

Course Outline: The content of the course was developed by the instructors as revised version of the outline for the robotics summer outreach program at Temple University. Revisions were made in order to give the new set of students more time to accomplish the work and also exempt course materials (such as programming of speakers for the robots) that were not applicable to deaf students. The course began with an introduction to basic circuit theory such as resistors, capacitors, series-parallel circuits, on a simplified level since students had no prior introduction to such topics. The students then went through the process of assembling the robots, during which they were given detailed explanations of the purpose of each component and how it works. Figure 2 below shows one of the robots assembled in the initial stages of the course, before students got involved with building circuits on the motherboard.

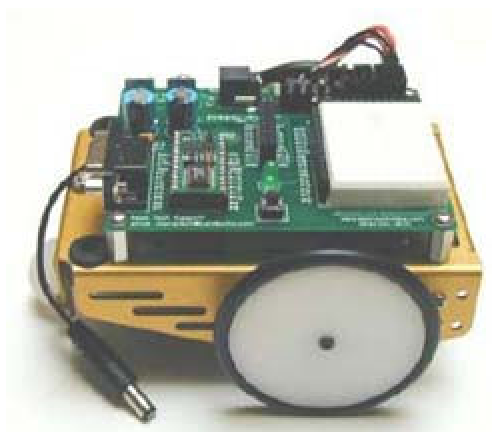

Figure 2: Example of robots assembled and controlled by ninth graders at the Pennsylvania School for the Deaf.

Some important components they learned about are servos and the Basic Stamp II chip. They were also taught how to control the pulse-levels sent to the servos through the Basic Stamp chip, and he significance of the varying levels. The next stage involved programming the robot to make turns using FOR loops, If conditions and sub routines. Students then received a lesson on RC-circuits and the time constant concept, to prepare them for controlling the robots using photo-resistors. They built

RC circuits on the motherboard (shown empty in Figure 2) and learned to program their robots to respond to light changes as well as color variation. Although the course was modified from the original to accommodate the fact the students were high school (and not college) freshmen and topics such as frequency modulation, infrared detectors and LED circuits were omitted, most of the fundamental topics in electrical engineering and programming were covered, and students were able to observe their implementation. Table 1 below shows the course outline for the 12-week period.

Table 1: Course outline for robotics course held at The Pennsylvania School for the Deaf

Week	Activity
1	Introduction and Course Overview Introduction to basic circuit theory
2	Simple engineering circuits and how they work.
3	Introduction to autonomous robots Assembling your robot
4	How servos work
5	Controlling your robot
6	Making turns
7	EEPROM
8	Making your robot see - Robots and lights 1
9	Making your robot see - Robots and lights 2
10	Making your robots feel - Robots and obstacles 1
11	Making your robots feel - Robots and obstacles 2
12	Final Competition and Award Ceremony

Pedagogical Considerations and Didactic Strategies: The following are some important factors that had to be considered during the program, and the corresponding tactics employed.

1. *Students were more visual*: One obvious factor was that the learners were deaf or hearing impaired, so the class could not be run in the traditional way, wherein students had to read handouts before class, and the material was explained in more detail at the beginning of the class. In this case, even though an interpreter was used, visualization was an important key to effective communication, since the learners were more visually alert than traditional students. Power-point presentations were developed specifically for the program, with several animations to illustrate the lesson. Figure 3 below is an example of an animated slide used to show how the robot could respond to light changes with the help of photo-sensors. The slide was designed such that as the light source moved around, the wheels would follow in the same direction for a light following task, and in the opposite direction for light avoiding. While this may seem quite obvious to any hearing person, the students clearly showed better understanding after they saw the illustration. In addition to Presentations, it was also

necessary to use the blackboard constantly when answering students' questions; explanation of circuits, pulse controls and even code were more effective when the students could see illustrations on the blackboard as opposed to signed interpretations of the instructors' words. The fact that English was a second language, and probably only a reading language for most of the students had to be taken into account, as the English reading level of the students were not as high as their hearing peers. Consequently, they were not expected to read the regular text handouts or other text-only resources as independently as traditional students. All information in these resources had to be made more visual for the students

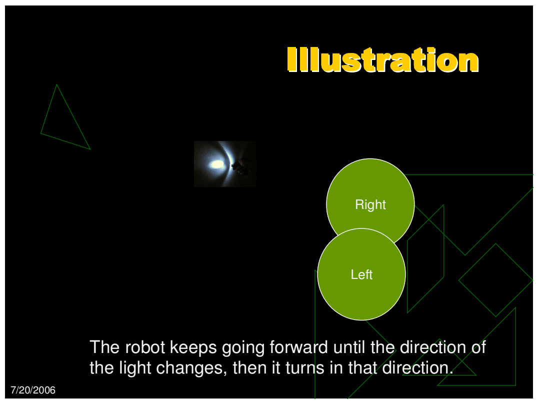

Figure 3: Example of animated slide used to illustrate the concept of light following.

2. *The material was new to the students*: Since learners were in their first year of high school, they were expected to have little or no background whatsoever on most of the topics taught. Therefore, no assumptions could be made about their knowledge of the subject. All lessons were taught from scratch, including fundamental mathematical concepts such as algebra. Simplifications had to be made to some of the concepts in order to give students a better understanding. Furthermore, some of the vocabulary was new in deaf education, hence it was sometimes necessary to develop new signs that the students could relate to. For example, no sign existed in American sign Language (ASL) for the phrase, "dead-band", which was used frequently (in reference to the maximum difference between the resistances of the two photo-sensors on each robot); thus a new sign which could easily be remembered was created by the science teacher in collaboration with the students.
3. *The course was taught by hearing persons*: Previous researchers in the field of deaf education have observed that students are more receptive and attentive to teachers who understand and can relate to deaf people, and who can sign.[6] The two instructors of the course were hearing, and had no prior experiences with people who were deaf, so it was important to have the some teacher-figures present who were also deaf or hearing impaired. The presence of the science teacher and the technical aide for the school, who were both deaf, but quite knowledgeable in science, alleviated this problem a great deal, as students were able to relate to them easily especially at the initial stages of the course. Also, the interpreter was quite adept at her job, making sure information was appropriately and swiftly passed to students, teacher and everyone else present. It was also helpful for the instructors to device a means of direct communication with the students, as, sometimes, several students needed individual assistance simultaneously. At first, the instructors communicated directly with students through writing on the board or on sheets of paper, but they gradually learned basic ASL and

began signing to students. This not only enhanced the line of communication, but gave students a sense of warmness and welcome, and definitely improved their learning process.

4. *The course was relatively difficult*: Learning Electrical Engineering, regardless of how much simplification is made to the material, is expected to be a hard task for high school freshmen. Moreover, as mentioned earlier, the reading level of the student was lower than that of their hearing peers. There was therefore a tendency of boredom and disinterest, especially when the concept was difficult to grasp, as students would sometimes give up and wanted the work to be done for them. This problem was resolved by the introduction of competitions after each new lesson. Students had to make their robots follow shapes, go through mazes, follow light paths, and so on, and the student who completed the task first was presented with an award. This showed an explicit increase in the students' interest in the course, as well as their collaboration with one another. Students were observed to try to learn from their peers who were able to complete their tasks with relative ease. Some students also assumed leadership roles, while others discovered aspects of technology at which they were skilled. At the end of the course, there was a final competition, during which students programmed their robot to go through a course similar to that shown in Figure 1. The robot which completed the course with the least errors in the least time won the competition, and its owner was presented with a prize, along with an award, which was also given to all participants for encouragement.
5. *This was the students' first experience in Engineering*: This course gave the students' their first impression about Engineering, and so their feeling towards it would affect whether or not they would go on to be engineers. Due to this fact, care was taken to ensure that they were not frustrated by difficulties, and that they saw themselves come up with solutions to problems independently. This would give them a sense of capability, and hopefully ignite their interest in studying engineering. It was also important to gain feedback constantly from students so as to learn how to improve the course to their advantage. To this end, they were made to write journals after each lesson, explaining what they learned, what they expected, and what could have been done to make their experience in each class better. These journals were reviewed weekly, and modifications to the class structure were made as deemed appropriate.

Challenges Faced: Being the first time such a program was conducted, some unforeseen challenges were faced, nevertheless, attempts were made to circumvent some of them, as explained below.

1. *Interpretation:* the use of an interpreter was expedient to the program, however, she had very little knowledge about science or technology, thus several terms and concepts were quite difficult for her to interpret, especially when signs did not exist for them. To prevent confusion in class, she was always provided with the material for class before hand, and she studied it carefully and tried to get familiar with some of the common terms. Moreover, whenever she got stuck interpreting a difficult concept, the science teacher, who was more knowledgeable in the area, picked up the ideas and gave better explanations to students.
2. *Lack of time and resources:* classes were held on PSD premises, and there were only 4 computers (for 8 students) in the most equipped room available. This meant that students had to share computers, and, since the class only lasted for two hours a session, some students were not able to complete their assignments. It was also impossible to extend hours as the course was scheduled during the last period, and most students had to take the bus home immediately after. An attempt was made to resolve the issue by having students work in teams of two. While this was beneficial in terms of time management as well as the

development of teamwork abilities in the students, it posed a problem sometimes, one team member advanced faster than the other, who would end up either copying the code off his partner or getting frustrated and discouraged at his own progress.

3. *Too much simultaneous communication:* Although it was advantageous to have two external instructors and three PSD staff members in class with the students, Simultaneous communication sometimes created a sense of disorganization. This occurred mostly when the science teacher was explaining difficult ideas to students, and the instructors would interrupt, unaware that a lesson is already going on. The interpreter did a good job of avoiding such situations by consistently interpreting everything that was being signed and said by everyone present in the class.

5. Evaluation and Results

Two forms of evaluation were performed at the end of the course, namely: formative and summative evaluation. Formative evaluation is one where the subjects provide critical information that could be useful in improving the program and enhancing results. Summative evaluation, on the other hand, involves an assessment of the success of the program and how well goal were met. In this section, the evaluation process is explained in detail, and results are analyzed based by relating the summative evaluation questions with the program goals, which are outlined in Section 1. Evaluations were performed by the high school science teacher and the students. The evaluation requirements, and every statement on the evaluation sheet was explained thoroughly to students by the interpreter and the science teacher, and they were allowed to ask for help if they had any confusions.

Formative evaluation: Table 2 shows the statements which were given to the teacher and students. They were asked to indicate how true they were on a scale of 1 to 5, 1 being absolutely false and 5 being absolutely true. The table also shows the average numerical response to each question.

Table 2: Formative evaluation of PSD Robotics Program

	Statement	**Average Response**	
		Students	**Science Teacher**
1	This course was taught well	4	3
2	This course was well organized	3.5	4
3	I would like to have this course taught again at PSD	N/A	4
4	Sufficient visual aids were used in this course	3	3
5	This course met my expectations	4	4

In addition to the questions shown above, the students and the science teacher were also asked to give general comments about the course, the most important lesson they learned, and what they would like to see improved. Some significant comments given by the science teacher are as follows:

"I think an important lesson students learned was to persevere through trial and error"
"My students are visual learners, so more visualization would be helpful"
"I enjoyed seeing the students' faces as the accomplished a task – they learned that hard work will eventually pay off"

While this section of the evaluation was somewhat encouraging, the second comment, as well as the response to the fourth question clearly demonstrates the importance of visualization, as, even though animated power points slides and blackboard illustrations were used in lessons, they were not sufficient for the course. A solution could be to make the course entirely visual, with text used only when absolutely necessary.

Summative evaluation: Tables 3 and 4 gives the same information as Table 2 but for summative evaluation. Table 3 shows statements presented to the students, while Table 4 shows those presented to the science teacher.

Table 3: Summative evaluation of PSD Robotics Program - Students

	Statement	**Average Response**
1	This course increased my interest in science and technology	3.5
2	I would like to continue with this course or enroll for a similar course if given a chance	4
3	This course helped me understand electrical and mechanical systems	3.7
4	This course helped me understand computer programming	4
5	Having taken this course, I think I can succeed as an engineer or scientist	3.75
6	I understood the material that was presented to me, and learned a lot	3.8

Table 4: Summative evaluation of PSD Robotics Program – Science teacher

	Statement	**Average Response**
1	Because of this course, my students showed more interest in science related subjects	4
2	I believe some of my students will go on to study Science, Technology, Engineering or Math related courses as a result of this program	4
3	My students grasped the basic concepts of this course well	3
4	I saw an improvement in my students' science and technology skills as a result of this course	4

The implications of these responses are discussed in the next section, in which the program is evaluated based on how well the goals were met.

Results: the assessment of the achievement of each of the objectives given in Section 1 is hereby described, with reference to the summative evaluation statements that correspond to each goal.

Objective

1. *To increase engineering awareness and encourage the desire for engineering education amongst high-school students who are deaf or hearing impaired:* The corresponding statements in the students' and teacher's summative evaluation are statements. The rationale for relating these statements to the objective is quite explicit.

2. *To present engineering in a method that is suitable for pre-college students who are deaf or hearing impaired*: The corresponding statements were 3 and 4 for the students' evaluation, and 3 for the teacher's. If the students as well as their teacher indicate that they understood the basic concepts presented in this course, it meant that engineering was presented suitably to the students.
3. *To give deaf students a sense of self-confidence and anticipation of success amidst the vast rate of technological advancement in today's world*. The corresponding statements were 5 for the students' evaluation and 4 for the teacher's for quite obvious reasons.
4. *To demonstrate to the students that communication for them is not limited to those who understand sign language and know how to sign, and to the hearing, that communication goes beyond speech*: the corresponding statement was 6 for the students, as, if they were able to understand the materials taught by hearing instructors, then it was well communicated to them, and so their inability to hear and/or speak was not an insurmountable barrier to their education.
5. *To make a statement, to all that everyone can learn engineering – it is a thing of the mind!!*: This goal was assessed by means of a concept competition in which the students' also participated at the end of the program. They were given 10 questions on engineering and programming concepts that they were expected to have learned during the course, and an audience consisting of the press, family, friends, the members of the board of directors of PSD and their colleagues was present to watch them attempt to answer each of the questions in teams of 3. The questions had not been revealed to students before hand, and amazingly, every team got each of the questions correct. Figure 4 shows one of the questions, which were presented to the students using power point slides.

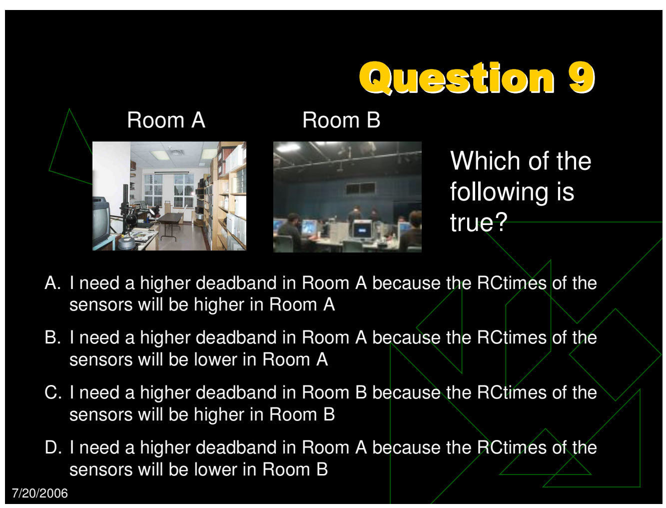

Figure 4: Example of questions for conceptual competition

Students giving a good performance in this competition revealed to everyone present (or those who could be reached by media) that engineering could be learned by all, and is not limited to hearing or speech.

A general overview of the performance of the program in achieving the above goals is given in Figure 5, which is a representation of the average response scores for each objective based on its corresponding evaluation statement. The black bars represented the responses from students while teacher's responses are shown in grey. The score for the fifth goal was obtained by scaling the number of questions answered correctly down to 5 (i.e., dividing it by 2 since there were 10 questions).

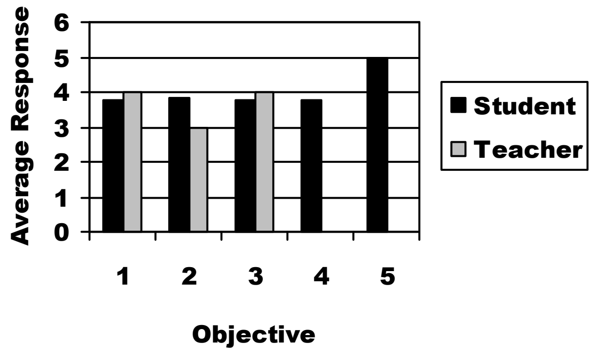

Figure 5: Performance analysis of PSD robotics program based of summative evaluation.

From Figure 5, it can be observed that the fifth objective was the most accomplished, with the second being the least. All responses are above 3, which is encouraging; however, no goal was accomplished above a ranking of 4 based on students' and the teacher's evaluation. This certainly indicates that there exists ample room for improvement for programs such as this. Lack of excellence in performance could be explained by the fact that this was an initial trial for such programs, which could further developed based on comments and responses to evaluations, as well as observations by the instructors and director of the program.

6. Conclusion

In general, the program presented could be considered somewhat successful based on the results of the evaluation. A similar but more developed and organized program will be run again, and an improvement in the level to which the goals were achieved is anticipated. One major goal of this paper was to propose strategies for presenting engineering to nontraditional students and some methods for addressing concerns related such undertakings. Results of the PSD robotic program, which was run using these tactics, have been shown. Enhancement ideas for the program will be derived from comments and observations by all the participants of the program. Some of these enhancements are: 1) the use of visual aids for every lesson taught, 2) a more detailed and much more visual explanation of circuit theory and programming and 3) quizzes at the end of each topic to monitor each students progress in learning the materials presented.

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