Session # 1661

Middle School Science Using Robotics For LEP and ESL Students

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Abstract

There is a need for more effective science teaching strategies for science teachers with large numbers of Limited English Language (LEP) students in grades seven and eight. The nature of science lends itself well to concrete activities that offer students the opportunity to, not only learn English vocabulary, but to gain a better grasp of concepts when associated with inquiry and hands-on learning. We present the results of a project* that used robotics to teach MS physics to LEP students in regular classes, English as a second language (ESL) students and LEP students in a voluntary after-school program sponsored by Mathematics, Engineering, Science Achievement (MESA). The project was in collaboration with engineering, physics, education and the local school district to train middle school (MS) science teachers who teach high minority populations. The paper describes how robotics was used to (i) address the physics part of the grade eight state physical science content standards of Nevada, and (ii) indirectly address the national science education goals of promoting science literacy and inquiry thinking in all students. We also address the connection of robotics to physical science content and pedagogy, as well as engineering principles. We explain how this was used to motivate students by connecting science to society. Even though the results of this project are directed at predominantly LEP and ESL students of Hispanic origin, the paper addresses the issue of improving student achievement in multicultural societies. It focuses on the need for both different teaching strategies and different curricula for underserved (LEP and ESL) students in grade eight science to improve their science achievement. It discusses why underachieving students need curricula that apply and connect science to societal needs more than students from generally more affluent families.

The content is significant in several ways. First, pedagogical content knowledge (PCK) and curriculum to make science more interesting to underserved students is discussed. Second, the possibility that better science teaching strategies may motivate more underserved students to pursue more challenging science courses is discussed. Last, the potential for increasing job opportunities and increasing the human pool for Science, Technology, Engineering and Mathematics (STEM) in a technology driven society is discussed.

* This work was supported in part by the William & Flora Hewlett Foundation Engineering Schools of the West Grants Initiative.

I. Background

Our experience in observing secondary science teachers who have science classes with high LEP enrollments indicates that many, if not most, still use predominantly teacher-centered instruction. The typical class format is based on lecture, and supported by the use of transparencies on an overhead projector. The science content is usually presented by direct instruction with very little associated lab work or teacher demonstrations to embellish the lectures. The students are generally expected to write down what is on the transparencies as the teacher explains them, and later use their notes to answer questions on a handout. This type of instruction certainly has a place in teaching but its value to real understanding of science if used day after day is questionable. State standards are tested with paper and pencil tests that are predominantly multiple choice questions and that generally only require recall of science concepts, not understanding. This type of instruction may prepare students to pass the high school science exit exam, but will it lead to an understanding of and appreciation of science? In observing and speaking to science teachers who predominantly use this type of instruction, they usually defend it by saying they do not have enough materials to have a lab program and the underserved students, generally LEP students, they generally teach, feel comfortable with this method of learning.

Although research on the use of science to develop language acquisition is not widespread, what research the authors found indicates that concrete materials (science materials and equipment) and student group work in science lab activities, can accelerate second language acquisition[2, 5]. Recent research by Gibbons[5] with fifth grade science students, comprised of over 90% of speakers of English as a second language (ESL), indicated that the use of science materials (magnets and associated materials) and group work, led to the use of more spoken English and the learning of associated science terminology. Intuitively, a veteran teacher would expect that the materials and social interaction alone would lead students to see the science as more interesting and relevant, and according to brain research on learning, this alone would lead to more learning[6]. Furthermore, research by other educators supports the value of peer-peer or social interaction between students for joint construction of knowledge[4, 10, 12]. Vygotsky also argued that mediation is facilitated by tools, cultural practices and artifacts[12]. Perhaps science materials and equipment can be thought of as analogous to tools and artifacts for mediating language learning in LEP and ESL students? To attempt to give a theoretical underpinning to this idea for this paper, Vygotsky's ideas are further elaborated upon. Within the construct of Vygotsky's Zone of Proximal Development, lab groups and science material can be thought of as providing the scaffolding for students to attach new vocabulary to during peer-peer discussions and teacher coaching. This is during the time when students make observations and try to use new science vocabulary to verbalize what's happening during science investigations. Lantolf[7] would perhaps call the peer-peer discussions and teacher coaching during the lab activity, a social form of mediation. Furthermore, when the 5E teaching Model[11] is used in laboratory activities, students have time to *Explore* (the second and probably most important E for science learning) science topics using science materials and to discuss their observations with their lab group members. They also have the opportunity to extend what they learn in science by applying and connecting it to society in the fourth E, *elaboration*. The last E, *evaluation*, is generally not addressed until the new science content and skills have been taught.

II. Methodology

Curriculum Materials and Units: The curriculum materials were taken from the Robolab CD[3], a book[13], and robot kits. The teachers took a one-week workshop in the summer of 2003. The robotics instructors were engineering graduate students from the University of Nevada. After one week of training that consisted of 30 hours of instruction, the teachers had built, programmed and tested their robots. They learned how to use several different sensors, a variety of gears and up to two motors to move, stop and turn the robots. A physics instructor was also present to discuss and demonstrate how to use the robots for the Forces and Motion unit in the grade eight standards. One science education person integrated science teaching pedagogy when time permitted. Class members also discussed and wrote several activities that could be used, with revisions, in the MS science classes.

When the teachers returned to their classes in the fall of 2003, they were charged with designing units on robotics to teach the MS physics standards with hands-on technology driven labs. To this date, three of the ten teachers have nearly completed their units, two more recently started and two more are due to start when they get more computers. Two of the engineering graduate students have visited the three teachers and given engineering presentations to the students that answered the following questions: What is an engineer? Who are some famous engineers? Why are engineers important? What is the difference between an engineer and a scientist? What are the different types of engineering? Why become an engineer? How do you become an engineer? In addition they talked to the students in detail about mechanical, electrical, civil, and computer science engineers since those are the main fields offered in most engineering programs. As a result of the presentation, the students know a lot more about engineers and have a clearer sense of how to prepare for a career in engineering. As might be expected from middle school students, some of them liked the idea of perhaps becoming a nuclear engineer to design bombs or a computer science engineer to design video games. One-half of the presentation was given in Spanish to the ESL class since all of the ESL students were Spanish speakers. In that class, the students asked most of their questions in Spanish. It appeared that having an engineering student from Mexico overcame the language barrier, and what he discussed about university work was inspiring to these kids.

A disadvantage of the program is the cost of the materials, the need for specialized training and the need for so much technology, especially the number of relatively modern computers.

Subjects: The subjects were Middle School (MS) grade eight students from three different MSs of approximately 700-900 seventh and eighth grade students in each school in a medium sized metropolitan area in the Western United States. The school district had approximately 60,000 total students of which approximately 35 percent were minorities and 25 percent of the total district is of Hispanic origin. The increase in students of Hispanic origin is about fifteen percent a year. One of the schools was comprised of a majority of middle class white students and two schools were comprised of predominantly lower-middle class to upper lower class minority students. Those two schools are classified as at risk schools. Each school had a separate ESL class with students attending some of the regular classes. Different groups of students were targeted for this study in each of the three schools. Group I was from the predominantly middle class school. It was a regular grade eight physical science class with 32 students. Group II was a class of 26 ESL students from one of the at risk schools. Group III was comprised of 13 students in a voluntary after school program, Mathematics, Engineering, Science Achievement (MESA) in the other at risk school (see Table 1 for a break down of the groups by gender, age and ethnicity).

Table 1. Break Down of Groups by Gender, Age and Ethnicity.

	Age		Gender		Ethnicity					
Group	13	14	M	F	AA	Asian	Cau	His	NA	Other
I	26	6	16	16	2	2	14	12	1	1
II	14	12	13	13	0	0	0	26	0	0
III	11	2	10	3	2	2	0	9	0	0
Totals	51	20	39	32	4	4	14	47	1	1

AA = African American, Cau= Caucasian, His = Hispanic, NA= Native American, Other = all others.

Instrument: The data was collected qualitatively with three cases[1], each teacher from the three schools. The three teachers responded to the following 9 questions during an interview by one of the authors:

1. How does the robotics unit address the physics part of the grade eight state physical science content standards[9]?
2. How did the unit address the national science education goals of promoting science literacy and inquiry thinking in all students[8]?
3. Was the physical science content and the pedagogy used to teach it made more relevant and interesting to the students because of its connection to robotics and engineering principles and design? Explain – Bring in the MS Technology Design Standards[8].
4. Are different teaching strategies and curricula needed for LEP and ESL students in grade eight science if we are to improve science achievement of these often underserved students? Explain.
5. To make science meaningful, do LEP and ESL students need a curriculum that applies and connects science to societal needs more than students who are native English speakers?
6. Did you use the 5E Teaching Model in any of the lessons? If so, was it a more effective teaching model than other teaching model/s you were using? Why?
7. Do your LEP, ESL and other at risk students see science classes as dull and tedious and of little relevance to the rest of life outside the classroom? If yes, did the robotics unit do anything to dispel this view? Explain.
8. Do you think that better teaching strategies and models as well as curricula, especially those that have more applications and connections to society[15] can help students see, 1) the value of science in their lives, and 2) see the need to be science literate, if they are to be informed citizens in a modern technological society?
9. If we think of the robotics materials and lab groups as providing the scaffolding, can you think of any classroom examples where the materials and group interaction led to more discussion in English and the learning of and use of new terms in science?

III. Results

The principal research question this paper addresses is the following: Does teacher application of science pedagogy that uses hands on inquiry, group work and science materials make science more interesting and learnable to underserved (ESL and LEP) students? The teacher interviews using the above 9 questions were used to answer this question. The responses of the three teachers for each question were compared to determine if they differed according to the types of students addressed; e.g., regular class, LEP, ESL or the voluntary MESA students.

The science teacher of Group I, a regular grade eight physical science class, gave the following responses, with some editing by the author who carried out the interviews:

1. The robotics material and computers gave another dimension to teaching physics. The students were able to learn by problem solving and using their inquiry skills as they constructed robots that would not fall apart when used. They realized early on that durability of the robot was more important than aesthetics. The unit is taking longer that I figured since LEP students need more time for instruction and more time and help to build the robots. They are less likely to have had experience with computer use out of school. In general, they may not have had the opportunity to play with Lego toys and other toys that require small motor coordination for construction. When compared to the control group class, they found the use of the robots to calculate speed to be more interesting, relevant and more accurate.
2. The students found the use of the robots more interesting because the groups were actually problem solving as they went along. I had given them some articles that dealt with robots as products we use. For example, the local police bought one to use with bomb squads. Also, the use of robots in the some of the mars probes. We also discussed the one probe that crashed into mars because of miles being mistaken for kilometers in the distance calculations. They had also read about robots being used for undersea exploration and salvage in the MS science magazine, *Science World*.
3. The small group work and robotics materials made the study of the physics content more interesting. The students also recognized that those robots were designed by people, engineers, and this made their own work more interesting and relevant. The students began to realize that technology and science are separate and people who develop technology such as robots, must learn science. I did not use the Science and Technology standards for technological design (8, p 161). I need to put more science terms into the lessons that I want them to use in the discussions. They have learned words like friction (they found out first hand that for speed the fat tires may not be the best), acceleration and velocity and they use them in the discussions. The students who work most with the computers are now commonly using the computer terminology such as software, firmware and download. During the programming of the robots, the pictures in the support materials helped the LEP and the other students as well, learn the commands much faster than reading about them. I discovered the pictures in the support material as I was looking through what was on the teacher CD.
4. All students benefit from the connections and application to society. The LEP students do benefit more from concrete materials and real life connections of the science that is taught in the classroom. The attitudes of the students are better and they seem to be more creative because of the materials they are able to work with[15].
5. I don't think so. All students can benefit from such a curriculum. A richer curriculum might help make up for the lack of outside experiences that more affluent children have.
6. I did not use the 5E Model in a direct fashion. Most of the instruction was informal with small groups and one on one coaching and writing 5E Model lesson plans did not work well with this. The exploration part of the 5E model fitted in with inquiry and problem solving when

they built and tested the robots. The elaboration part would fit with the applications and connections of the robot unit to society.

7. The robotics curriculum has made it more interesting for kids coming to science. It seems to heighten their awareness and give them positive feelings about science. When they are successful in building, programming and testing the robots they feel better. They look forward to class more than my other classes who are sometimes jealous because they do not get to use the robotics materials. Block scheduling can be good and bad. The longer lab block is good but missing days in between sometimes destroys the momentum they have and when they return they have to review some to get back on track. I have let the class be less structured or less directed because some groups are faster than other. As a result, instructions are more open ended. Next time, I will give more time in the beginning to just fool around with the materials, e.g., the Lego blocks. I also think if I had spent a little time with simple machines such as gears and wheels beforehand, they would not have struggled as much in figuring things out. I could have done a simple machines lab with a variety of stations to prepare them for the robotics.
8. The hands-on teaching strategies with materials that can connect to everyday life do seem to have more value to the lives of students and as a result they could become more science literate if taught more in this way.
9. There is an interaction within the lab groups as well as between the teams. When one group discovers something, one person from another group will go to that group to see what they did and how they might use it. One girl is more computer savvy and she shares with the others. There is more camaraderie with the cooperative groups and science materials and equipment. The computer value is strong as well, not just the physics and technology from the robotics. One Hispanic student was willing to explain what he had done to the class with some prompting and encouraging and as a result he seems more confident about using his English to explain science.

The science teacher of Group II, the ESL group, gave the following feedback with some editing of her answers by the author:

1. The unit included velocity, acceleration, speed, power, units such as Newtons, and a lot of science inquiry including problem solving skills and math skills associated with designing tables to record data and graphing data.
2. Students worked in small groups of four with two assigned as builders and two as programmers. The small group work helped them discuss and engage in inquiry as they built the robots, programmed them, tested them, programmed them again and retested them. Even such things as connecting the wheels to the motors required inquiry to get it right. They learned about the sturdiness of the robots to make them more durable so they would not fall apart during testing. They use the words durable and sturdy in discussion and made them a part of their vocabulary. We also discussed the use of robots in society, especially the Mars landing crafts.
3. The pedagogy was intended to help students use everyday language and science language as they designed and built the cars (robots). The small groups of four helped them do this as they discussed what to do. I had them use spring scales to learn about friction and the force needed to overcome it on level ground with different surfaces. They immediately applied this knowledge to their cars to reduce friction by changing the wheel size. Perhaps as many as 50

percent of the students had used Lego toys before the unit. This speeded up some of the building since the students in some cases already knew the function of the parts for spacers, reinforcement, etc. The small groups and materials that connected the science to real world technology did make the learning of the science and everyday English more interesting to the kids. I made them talk everyday to discuss what they were doing and how it was working.

4. ESL and LEP students need more direction for what vocabulary to use and practice. Visuals certainly help in developing vocabulary as well. I gave words to use each day and I had them talk at the end of each class. They also had quizzes over vocabulary and I gave demonstrations to small groups on how to build sturdier cars. I dropped mine to show that it would not break because it was sturdy even though it might not look as nice as some that did fall apart and were not durable. I also demonstrated how to use the Pilot I program to change the time in the robots. I did a lot of coaching and demonstrating to small groups when they needed help rather than addressing the entire class. They also learned how to estimate and extrapolate by trial and error as they inputted the time in the robots for a certain distance they wanted them to travel before stopping (See the "Going the Distance" Activity). They graphed it afterwards. I had to give some lazy kids worksheets a few times and this motivated them to work harder in the lab.
5. Kids learn a lot from TV but I still think ESL and LEP students may need more outside experiences or at least more direct or obvious connections to show the applications of science to society. To help with this, two engineering graduate students that helped with the program came in and gave a presentation on engineering and answered questions from the kids about what engineers do and what students need to do to prepare for an engineering career. One of the graduate students was from Mexico and he spoke Spanish to the kids when he answered their questions. The kids were very motivated about engineering after the presentation. During "Back-to-School Night" I talked to many parents about the robotics program and demonstrated some of the cars their children had built. The parents were excited that their children were getting to use this kind of equipment.
6. I used the 5E model but I did not make an attempt to use each part. The fourth E or Elaboration may be the most useful E in this type of small group instruction using specialized materials. Exploration is used a lot anyway.
7. My students do not see science as dull and tedious. This is the first time many of them have gotten to use science materials and they really like it. The ESL students have not been in the US long and they have good attitudes toward school. They are polite and they treat teachers well. They still want to do well in school. They realize that engineering has relevance to their lives.
8. These students already seem to realize that science has value in their lives. Direct connections may need to be made to show that science is necessary before one can develop technology. Technology is based on science principles. It probably has to be directly taught if most students are to realize that knowledge of science is needed to be an informed citizen in a modern technological society.
9. The robotics material allowed the students to learn many words and use them in discussion. These words, they otherwise might not have come in contact with in everyday conversation. Words like electrical cords, output and input, electricity, download, software, connections, wires, lights and laser sensors, wheels, traction, hubcaps, axles and many others were introduced to the kids as they built, programmed and tested the robots. The small groups,

robotics material and other materials, all provided a medium and concrete substance for the new vocabulary. The small group discussions helped them practice the new words. Without the unit, many of the words would otherwise have not come up. The girls even got a chance to talk about the robot parts as they applied to bicycles and cars and for the first time some of them learned about car stuff that boys take for granted. I gave students homework to discuss science and technology with their parents using the new vocabulary. Many of them got additional practice in this way.

Additional comments by the ESL science teacher. I believe in doing fewer labs than some of the other science teachers but I believe in going much more in depth with the vocabulary. Perhaps the learning process that the lab work allows is more important to an ESL student since the students learn new words as well as the procedures or processes needed to carry out lab work and this involves inquiry to learn new information. Many labs are so focused on teaching a science concept that they do not devote enough time to the process which has more transfer to other things. To cultivate a lasting interest in science with these students, you must grab it by the horns (the opportunity) before it slips away. My labs become open ended. The students may develop the procedures and the process. For example, in this lab, I had one group of super builders who built four cars in a 60 minute period. I assigned two super builders to a group that took a week to build one car. The super builders were so far ahead of the others that they could be used to help coach some of the slower ones.

The science teacher of Group III, the MESA group, gave the following remarks with some editing by the author:

1. The robotics unit addressed the Forces and Motion standard. This included concepts such as friction, acceleration, velocity and electricity since the robots were powered by the rechargeable batteries. The process and inquiry part of the standards were also addressed since the students worked in groups to problem solve how to construct and test the robots by trial and error. They also used organizational skills to construct tables, graphs and charts for organizing and reporting data.
2. Since the students, groups and individuals, did not follow a lab procedure, pure inquiry was involved much of the time as they decided how to construct the cars (robots) and tested them for speed and durability. They have not programmed them yet so we have checked speed by how far and how fast they will glide when let go down a ramp. Friction, velocity and acceleration have been the main variables that they have measured. The inquiry and exploration certainly supports the NSES but to this point I have not brought in science literacy regarding societal applications of robots.
3. The small group work by the students and use of the robotics materials makes the learning of science concepts more interesting to the kids. I have also done a lot of coaching of small groups and individuals who wanted to work alone. I could allow a few of them to work alone since I had plenty of materials. The robot materials served as the medium for the inquiry process and practice of problem solving skills. I did not intentionally use the MS technology design standards from the NSES, but in building, testing and redesigning the robots while they discussed what to do in the groups and with me was a form of technology design.[†]

[†] Content Standard E: As a result of activities in grades 5-8, all students should develop abilities of technological design and understanding about science and technology. Abilities of technological design should include being able

4. Visuals help for LEP students. It reminds me of the TV show of when the Brooklyn bridge was being built and the engineers and architects had drawn diagrams of the entire building process. I did not think about the workers as including so many non English speakers. With diagrams, they were able to build the bridge. This is analogous to the robotics kits that include a book of diagrams for robot construction. The kids were able to look at the diagrams and design different robots without my help. Having the concrete robotics materials to work with serve as visuals as well. The small group discussions also help the LEP students practice English.
5. No, I don't think that these students need science connections from the curriculum to society anymore than other kids. They all probably need it. What I notice about these kids in MESA is that they are different from most of their peers. They watch TV shows like Nature and Discovery a lot without being told because they are interested in the subjects. They seem to have an intellectual spark already, and I'm not sure where it came from.
6. The only part of the 5E Model I used to any extent was the Exploration part. To this point, the students are still building and testing the robots so exploration is still going on. Later, when I give more formal instruction we will use the third E, explanation, to talk about some of the science concepts. We will also use the fourth E, elaboration, to connect their work to applications of robotics technology and the science principles learned, to society.
7. These students do not see science as tedious and dull. They are voluntarily coming to this after school class a few hours per week because they like science. They see this robotics work as very interesting and they continue to be excited about what they are doing. I don't think they are aware of the relevance of science to their out of school lives now or in the future. The connections of school science to real life are probably connections that the science teacher must make.
8. More lab materials can help teachers make science more interesting and connect it to students' lives. Our school is short of money to buy science materials so materials such as these, through the grant, have really helped us teach more hands on science that allows for more societal connections. As I said earlier, any links of science to life outside the classroom probably have to be made by the teacher. At this point, I don't think students make a connection between science class and science literacy and the need for it to be an informed citizen in a modern technology driven society. Again, the teacher must make this link.
9. Yes, there are so many English cognates in Spanish and other languages that science is an ideal class for teaching science vocabulary. The students already seem aware of many of the computer terms and science terms because of their similarity in their native language to the English words. The computers and robotic materials have helped students use words such as download, software, connections, cables, friction, momentum, gears, pulleys, wheels, rims, treads axles, spacers, motor and sensors. I had to tell them the words for a lot of the robot parts when they were building them. Of course, the group work helps them practice these words in a real hands-on setting where they actually work with the materials that have these names or show (demonstrate) the science concepts when tested in the trials. I think that it is fair to say that the robotics materials and the small group discussions both aided students in learning the science terms and in practicing their English. These two strategies could be analogous to what Vygotsky described as scaffolding.

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to identify appropriate problems for technological design, designing a solution or product, implementing a proposed design, evaluating completed technological designs or products and communicating the process of technological design (NSES, pages 165-166).

Additional comments by the MESA science teacher: About 60% of these students have computers at home but in most cases their parents do not allow them to use them. Only three of them had Lego toys at home but most had played with them at friends or relatives houses. All are very active, attentive kids who like science and if asked why may not know, but will say they have always liked it. They seek out television shows that are science based, even though they may not know they are science based, and watch the shows because they find them interesting. We compared the three groups for each question and observed the following (See Tables 2 and 3):

Table 2. Similarities of Teacher Responses to the Nine Questions

Question/Issue addressed	Similarities
1. Physics Standards, content and process	All groups addressed problem solving and inquiry. This was aided by having the robotics materials to work with.
2. NSES of inquiry and science literacy	All groups were involved in inquiry/ exploration and problem solving.
3. Relevance and interest in the physical science content and the pedagogy used to teach it	All groups recognized that the robotic materials and small group work helped make the physical science content more interesting to learn. The robotics materials also made the physics content more relevant.
4. Do LEP and ESL students need different teaching strategies to improve their science achievement?	All teachers agreed that visuals or concrete materials can help LEP and ESL students develop vocabulary faster.
5. Do LEP and ESL students need a curriculum that connects science to society more than native English speakers?	All three teachers agreed that all students can benefit from such a curriculum.
6. Did you use the 5E Teaching Model in any of the lessons? If so, was it a more effective teaching model than other teaching models you were using? Why?	None of the teachers made an attempt to use all parts of the 5E Model in a formal lesson. They all agreed that the exploration part was inherent in the inquiry and problems solving part of the activities of the unit.
7. Do your LEP, ESL and other at risk students see science classes as dull and tedious and of little relevance to the rest of life outside the classroom? Did the robotics unit do anything to dispel this view? Explain.	All three teachers agreed that their students found the robotics materials very interesting and they like working with the materials.
8. Better teaching strategies, etc. 1) see the value of science in their lives 2) see the need to be science literate if they are to be informed citizens in a modern technological society?	There was no uniform agreement on this question.
9. If we think of the robotics materials and lab groups as providing the scaffolding, can you think of any classroom examples where the materials and group interaction led to more discussion in English and the learning of and use of new terms in science?	All three teachers agreed that the robotics materials helped the students learn new things and the ESL and MESA teachers emphasized vocabulary. The small group work helps all students learn new things and the ESL and MESA teachers singled out vocabulary again and the small groups that allowed students to practice the new words.

Table 3. Differences of Teacher Responses to the Nine Questions

Question/Issue addressed	**Differences in one or more groups**
1. Physics Standards, content and process	The ESL and MESA group (ELL) placed more emphases on using the materials to develop vocabulary and process skills such as data tables.
2. NSES of inquiry and science literacy	Both the teacher in the regular class and the ESL teacher discussed societal applications of robots. Pure inquiry was only used in the MESA class.
3. Relevance and interest in the physical science content and the pedagogy used to teach it	The students in the regular classroom realized the robots were designed by people (engineers). This made the physics content more relevant. The LEP student teacher pointed out that the small groups enabled students to use science and everyday language. The MESA groups' teacher also allowed some students to work alone and she coached students individually.
4. Do LEP and ESL students need different teaching strategies to improve their science achievement?	The regular teacher stressed that all students benefit from societal connections and applications. They also make students more creative and give them better attitudes toward science. The ESL student teacher stressed the need for teachers to give ESL students more direction on what vocabulary to use and practice and for more demonstrations. The MESA teachers pointed out that the *Mindstorms* robot construction book enabled her students to identify the parts and construct the robots just from the diagrams. She likened it to the building of the Brooklyn Bridge with workers who spoke no English.
5. Do LEP and ESL students need a curriculum that connects science to society more than native English speakers?	The ESL student teacher felt that ESL children learn a lot from TV but may still benefit more from outside experiences that have direct connections to science. The MESA teacher said that her kids watch television a lot; shows like "Nature" and "Discovery" that teach them a lot of science.
6. Did you use the 5E Teaching Model in any of the lessons? If so, was it a more effective teaching model than other teaching models you were using? Why?	Two teachers used or will use the fourth E, elaboration, to make connections to society. One said the third E, Explanation, would be used later to talk about science concepts.
7. Do your LEP, ESL and other at risk students see science classes as dull and tedious and of little relevance to the rest of life outside the classroom? Did the robotics unit do anything to dispel this view? Explain.	The ESL and MESA stated that their students do not see science as dull and tedious. The teacher of the regular class did not say her students saw science as dull and tedious but that the robotics curriculum made the class more interesting, heightened their awareness and gave them positive feelings about science. She said the science students doing the robotics unit look forward to science more than her other students who may be jealous because they are not using the robotics materials. The ESL student teacher said that students realize that engineering has relevance to their lives. The MESA teacher did not think her students knew the relevance of science to their lives and she felt that the teacher probably had to make these connections.
8. Better teaching strategies, etc. 1) see the value of science in their lives 2) see the need to be science literate if they are to be informed citizens in a modern technological society?	The regular teacher and the MESA teacher agreed that more materials can help teachers make science more interesting and connect it better to their lives. The regular teacher felt this could also lead to more science literacy. The MESA and the ESL teachers did not think students see a connection between becoming science literate and the need to be an informed citizen in a modern, technology driven society. The ESL student teacher thought this must be directly taught. She also felt that her students already realized that science has value in their lives. Direct connections may need to be made to show that science is necessary before one can develop technology.
9. If we think of the robotics materials and lab groups as providing the scaffolding, can you think of any classroom examples where the materials and group interaction led to more discussion in English and the learning of and use of new terms in science?	The MESA teacher mentioned Vygotsky's theory and that small group work and use of materials was analogous to providing scaffolding to learn new words. The regular teacher mentioned sharing of information between groups and the camaraderie the class developed during learning. The ESL student teacher mentioned that the materials had provided a platform for girls to learn about car talk. The MESA teacher mentioned the cognates in computer and science terminology for Spanish speakers learning English and how the robotics and computer materials help the students make the connections.

IV. Discussion and Conclusions

Regarding research question one: Does teacher application of science pedagogy that uses hands on inquiry, group work and science materials make science more interesting and learnable to underserved (LEP and ESL) students? In analyzing the teacher responses to the nine questions, regarding agreement of the three teachers (see Table 2), the following generalizations are made:

1. Working with the robotics materials helped students practice problem solving and inquiry skills.
2. The NSES goal of promoting inquiry was addressed in the small group work with the robotics materials. This work involved inquiry/ exploration and problem solving among the groups members and in some cases between groups as well.
3. Small group work with the robotics materials helped make the physical science content more interesting to learn. The robotics material also made the physics content more relevant.
4. Teaching strategies that use visuals and/or concrete materials such as those found in laboratory investigations, can help LEP and ESL students develop vocabulary faster.
5. All students can benefit from a curriculum that makes connections and application to society.
6. When the 5E teaching model is used, the second E or exploration part seems to be the most useful for laboratory work. The fourth E, elaboration, helps students connect and apply science concepts to technology in society.
7. The robotics material made the learning of science more interesting to the students.
8. There was general agreement that the robotics materials help all students but LEP and ESL students in particular, learn new things including science vocabulary. Small group work can be helpful for all students as well, but again, it was more helpful in teaching vocabulary to ESL and MESA students than other students because it provided a setting to practice new words.

Since the posttest in the associated physics knowledge that was expected to be learned for the science standards has not been given, there is no empirical data to indicate whether the students learned more than they would have in a regular classroom without the robotics materials. Also, only Group I of the three groups was matched with a control group. When asked, the students did agree that science was more fun in a lab setting that allowed social interaction with group work.

Other research questions that will be addressed with further study are: 1. Can better science teaching strategies motivate more underserved students to pursue more challenging science courses? 2. How can underserved students be made more aware of the job and career opportunities in Science, Technology, Engineering and Mathematics (STEM) and as a result become a larger proportion of the pool of potential employees in STEM careers in our technology driven society? Currently, no data is available to answer these two questions. A longitudinal study will be needed to track the underserved students who learn physics with the robotics materials and small group work to determine whether more of them take more challenging courses in science and mathematics in high school. The MESA program is aimed at getting more students to pursue careers in engineering and other STEM careers and it is more likely that more of these students would pursue engineering tracks with or without the robotics program support. The robotics program, the engineering speakers, the parents' nights and the monitoring of the students over the years may all lead to more of these students pursuing STEM careers after high school graduation, technical training or a four year college degree. Only time will tell and it is hoped that counselors can become more involved in tracking and encouraging these students.

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Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition