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Promoting Science and Engineering in Grades K-12 By Means of a Summer Workshop - A Universal Model –

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Abstract

During the summer of 2003, the Computer Science and Engineering Departments arranged and coordinated two one-week workshops for middle-school children. These workshops provided a wide variety of Science and Engineering-related lectures and activities. The activities were diverse, such as; experimenting with concrete and failure in compression, assembling electronic circuits, building and programming robots, working with Global Positioning Systems (GPS), learning the binary numbering system and using surveying equipment as well as several other activities.

The intention of the workshop was to promote science and engineering at an early age. However many additional benefits were achieved; some of which include:

1. Introducing the participants to the college environment
2. Providing a social atmosphere of teamwork
3. Giving the participants an educational and enjoyable week during their summer break
4. Providing the parents of the participants the opportunity to visit the campus, view the Computer Science and Engineering laboratories, and meet the science and engineering faculty / staff.

Studies have shown that there is a high probability that the United States will have a significant shortage of scientists and engineers within the next ten years and beyond. In the state of Utah, Governor Leavitt has declared an Engineering Initiative whereby a goal was established

to double the number of engineering graduates in five years and triple the number in eight years. Because of the above trend and the Governor's initiative, the Computer Science and Engineering Departments at Salt Lake Community College (SLCC) are working diligently to enroll more students in Science and Engineering programs. This was the incentive to offer such a workshop.

This paper will outline the steps that were taken to arrange and coordinate the workshop. It will include details of how activities were selected and prepared, how the workshop was promoted to the appropriate audience, how the participants were kept interested throughout each session, and how parents of the participants were kept informed. Successes and challenges of our workshop experience will be discussed and future possibilities described. This type of workshop could be used as a universal model to stimulate interest in science and engineering amongst children in grades K-12.

Background

Governments around the world have observed the successes of the United States during the prosperous 1990s. There was a growing conviction that the successes of the United States were, in part, due to the educated workforce. Other countries began to build up their work force at a faster rate than the United States. If other countries continue this build-up, it could cause both potential employees and companies to do business with these countries, thus diminishing the attractiveness of the United States. If this situation continues, it could become a challenge for the United States to continue to prepare a well-educated work force – especially in technical fields.

Gordon Moore, cofounder of Fairchild Semiconductor and the Intel Corporation, commented in the New York Times (2001): "[W]e're in danger of exporting a lot of technological advantage because we're not training enough people here. Education, that's our Achilles' heel."[1] Several factors have convinced others to feel the same way. According to the National Science Board Committee on Science and Engineering Indicators[2], some of these factors are:

1. As new centers of technological excellence arise, firms and universities in the United Stated may find it increasingly difficult to recruit scientists and engineers from abroad, currently an important source of supply.
2. During the 2000 – 2010 period, employment in Science and Engineering occupations is expected to increases about three times faster than the rate for all occupations.
3. The long-term trend has been for fewer students to enter engineering programs.
4. The total number of retirements among Science and Engineering-degreed workers will increase dramatically over the next 20 years.

Because of these factors, it is alarmingly apparent that, if the situation continues as predicted, the United States will have a significant problem hiring Scientists and Engineers. In view of potential peril to US strength in science and engineering, the National Science Board endorses the following imperative for Federal action:

RECOMMENDED NATIONAL POLICY IMPERATIVE
The Federal Government and its agencies must step forward to ensure the adequacy of the US science and engineering workforce. All stakeholders must mobilize and initiate efforts that increase the number of US citizens pursuing science and engineering studies and careers.[3]

These facts drive the faculty at the Salt Lake Community College to constantly seek new students to enroll in Science, Engineering and Computer Science programs. In addition, one of the pertinent mission statements of SLCC is "Community Services Education to provide services and activities that promote community involvement." As a result, a Summer Science Workshop was developed for teens, age 12 through 15. During the summer of 2003, the Engineering and Computer Science Departments at Salt Lake Community College planned and held two of these 1-week workshops. This event was such a great success that the Salt Lake Community College is planning to continue these workshops in future summers, with different activities each summer. This paper will outline the steps that were taken to plan and hold these summer workshops. In addition, successes and challenges of our workshop experience will be discussed along with recommendations for changes in future workshops.

Body

A. Planning

The planning for the summer workshops began at the beginning of May 2003 and the first camp began July 14, 2003. During the ten weeks between these dates, much planning had taken place. The basic steps to plan the workshops are listed below:

1. Meeting to make the initial decisions
2. Branding activities
3. Marketing activities
4. Detailed planning for each activity

Details of each of these steps are discussed below.

1. Meeting to make the initial decisions:

One person took the responsibility to be the workshop coordinator. The coordinator called an initial meeting to make the major decisions about the workshop. Because we were not sure of the activities that we wanted, all of the faculty in the Engineering, Computer Science, Mathematics, and Science departments were invited. The issues that needed to be discussed during this initial meeting included the activities that we were going to offer, the days and times of the workshop, the number of participants and the cost to each participant.

The group discussed whether the workshops should be focused on one type of discipline or whether they should cover numerous topics. Pros and cons were discussed for each approach, but it was decided that each activity would represent a different field of study. It was thought that this would provide a varied experience to the participants. If a participant had less interest in one activity, then it would be possible that that same person would have more interest in another. Furthermore, we felt that having several different types of activities would provide a broader knowledge base to each participant, thus opening their minds to numerous new areas of study.

Although many ideas were discussed regarding the content of each activity, it was decided that each activity had to meet several requirements. Some of those requirements were:

a. The activity had to be challenging to teens age 12 through 15
b. The activity had to use materials and equipment that the Community College already possessed
c. Some faculty member had to have expertise in the area
d. The activity had to be fun and motivating for the participants

We decided on six major activities. These included experimenting with concrete, assembling electronic circuits, building and programming robots, working with Global Positioning Systems (GPS), learning the binary numbering system and using surveying equipment. Details of each of these activities will be discussed later in this paper.

Next the group discussed the logistics of the workshop. It was decided that the workshop would cover one week (this meant Monday through Thursday since Salt Lake Community College was closed on Fridays during the summer of 2003). It was also decided that the workshop would start at 8:00 AM and end 12:00 PM. This would give us four hours each day to have one 4-hour activity or two 2-hour activities. It was decided that there would be a short break with snacks provided about 10:00 AM each day. The camp would take place mid-July. (Initially, it was planned to have just one workshop as a trial for this first year. However; there was so much interest that a second session was later added).

The group also had a discussion regarding the financial issues of the workshop. It was decided that each workshop would have 20 participants and a nominal fee would be charged.

2. Branding Activities

In order to create a cohesive feel to our workshop, we had to do some branding. This included agreeing on a name and logo. In addition, we created a flier and poster containing all of the pertinent information as well as the name and logo of the workshop. Additionally, a t-shirt was designed using the same logo that would be handed out to all of the teens and faculty who would participate in the workshop.

3. Marketing Activities

Since this was the first Summer Teen Science Workshop at Salt Lake Community College, we were not sure of the most efficient methods to get the word out about the workshop. We decided on a direct marketing scheme. We made numerous copies of the flier and distributed them to the middle schools/junior high schools in the area. It was decided that the mathematics and science teachers in each school would send a flier home with each of their students. About 10,000 fliers were distributed the first week of June.

In addition, we thought it would be advantageous to get some press in newspapers, radio or television. A press release was written describing the workshop and sent out to various media companies in the area. After sending the press release to several places, stories about our workshop appeared in a few small local newspapers. Also, a radio station that provides community announcements did a one-hour show with discussions highlighting the workshop. Several faculty from the community college participated in the discussions. Word was also spread at the community college itself using email and the college on-line newspaper.

4. Detailed planning for the activities

Prior to the workshop, there was still much more work to be done. Each activity was assigned to a faculty member. That faculty member was required to organize and present the material for the activity assigned. The faculty member assigned to each activity was the faculty member who is the expert in that field. For example, the faculty member that normally teaches Civil Engineering was the same person organizing and presenting the concrete activity, the faculty member that normally teaches Computer Science was the same person organizing and presenting the robotics and programming activity, etc. In addition, it was decided that two Engineering Technicians (already employees of the college) would help to prepare for activities in each of their areas of expertise as well as participate in all of the week's activities. And finally, in addition to the workshop coordinator being at each activity throughout the week, it was decided that two student helpers would be present as well. This resulted in the fact that there were at least six adults with the participants at all times.

Each faculty member was asked to develop a lesson that would be presented prior to having the participants perform the activity. The lesson was to be just long enough to be informative so that participants could perform the task with little help from adults. In addition, each presenter was to provide a chapter of information to be included in a notebook that would be handed out to each workshop participant. Each chapter would show what the activity was, information needed to perform the task and what would be learned from the activity. The coordinator met with each presenter on a regular basis to ensure that the material to be presented met the initial requirements for each activity. Also the coordinator gathered the material from each presenter, reviewed it to ensure completeness and consistency and placed it in the notebook. A notebook was made for each participant attending the workshop.

B. Communication with parents/guardians

It was decided that communication with parents/guardians was important and would treated with priority. Salt Lake Community College worked to ensure that parents were informed throughout the process from the day that they registered their child for the workshop to the very end of the workshop. We decided on the following forms of communication:

1. By phone:

A phone number was provided whereby parents/guardians were encouraged to call. This number reached a clerk in the Engineering and Computer Science office who would register the participant as well as answer any questions. The workshop coordinator provided the clerk with information regarding the workshop so that most of the questions could be answered immediately. In the event that the parent/guardian had questions beyond the knowledge of the clerk, a phone number was taken and the workshop coordinator called back to answer any further questions.

2. By mail:

Prior to the workshop, a letter was mailed to each person registered for the workshop. The letter included general information about the workshop (ex. dates, times, activities, etc.) In addition, a map was provided showing where the workshop was to take place. And finally, a list of rules that were to be followed by the workshop participants was included along with a procedure that would be followed in the even of a participant refusing to follow the rules.

3. By handouts:

A binder was put together and given to each workshop participant. The binder included a chapter on each activity including what the activity was about, instructions for performing the activity and what would be learned during each activity. Diagrams were included showing how the electronics circuit was to be built, instructions on how the robots were to be built, maps of the campus showing the check-points for the GPS activity and much more. Each participant was provided a binder on the first day of the workshop and was able to take it home each night. After the workshop was complete, each participant was able to keep the binder.

4. By open house:

It was decided that we would offer parents/guardians time to come in and see the outcome of the week of activities. We planned a two-hour open house on the last day of the workshop. This was in addition to the four hours designated for that day's workshop activities. Because the open house was held between 12:00 PM and 2:00 PM, we provided lunch for the participants as well as the parents. All of the faculty and helpers who participated in the workshop attended the open house. Parents/guardians were delighted to speak with the presenters and helpers about the activities as well as their child's participation in the activities. In addition, we had displays set up with the products produced during each activity. The teens were excited to show their parents/guardians the final products, often demonstrating how their products worked or describing what they did during the week. Tours of the various labs were also provided to parents who were interested.

C. The workshop itself

We thought that it would be important that the workshop participants work in teams. On the first day of the workshop, we had the participants split into groups of four. These groups worked together throughout the workshop. For some activities, the teams worked all together, for other activities, the teams split in half so there were teams of size two.

The workshop consisted of six major activities. The activities were diverse, such as; experimenting with concrete and failure in compression, assembling electronic circuits, building and programming robots, working with Global Positioning Systems (GPS), learning the binary numbering system and using surveying equipment. The activity having to do with concrete was split into two parts. Also, the electronics circuit that was made by the workshop participants was used as a tool during the binary numbering system activity. The weekly schedule was as follows:

Day 1	8:00 – 12:00	Assembling the electronic circuits in teams of two
	Various times	Mixing and pouring concrete samples in teams of four at various times throughout the morning
Day 2	8:00 – 10:00	Working with surveying equipment in teams of four
	10:00 – 12:00	Working with GPS in teams of two
Day 3	8:00 – 12:00	Building and programming robots in teams of two
Day 4	8:00 – 10:00	Learning the binary numbering system in teams of two (The electronic circuit built on day 1 was used during this activity)
	10:00 – 12:00	Compressing the concrete sample to failure and discussing the reasons for failure in teams of four

Each activity included a lecture given by the SLCC professor with the specific area of expertise as well as a hands-on activity. Each will be discussed in detail in one of the following sections.

1. **Assembling electronic circuits:**

This activity was in the area of Electrical Engineering. The activity was performed in teams of two. Each team was provided a circuit board, various parts, wire, wire cutter/stripper and two color photos of the finished product. The final product was a circuit that contained eight switches wired to a seven-segment display. If wired properly, the switches could be set to match the byte associated with an ASCII character, and that character would then be shown in the seven-segment display. (ASCII stands for American Standard Code for Information Interchange. Each character is assigned a series of eight ones and zeros that is understood by computers. For example, in ASCII, the character 'A' is represented as 0100 0001 and the character 'a' is represented as 0110 0000). The photo of the circuit that was provided is shown below:

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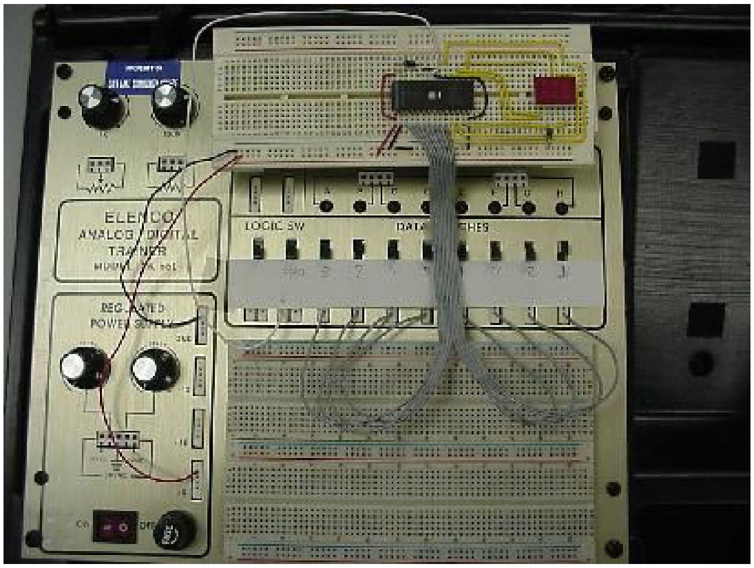
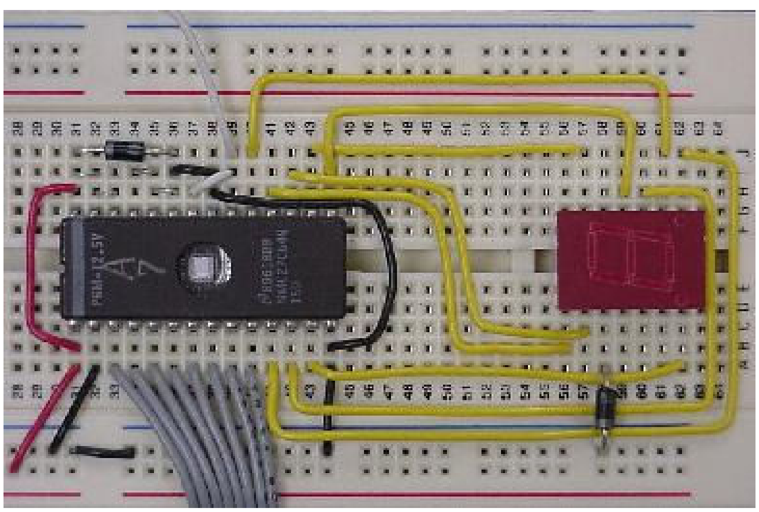


In addition to this photo, a close-up photo was provided of the small circuit board. This close-up photo is what the participants used to determine the locations where the wires would be placed. The close-up photo of the small circuit board is shown below:



2. Working with surveying equipment:

This activity was in the area of Civil Engineering. The activity was performed in teams of four. Each team was provided with a transit and designated a stationary point. Five markers were placed in a field and each team had to determine the location of each marker from the designated stationary point. Each team was also assigned to a different starting marker. Each team zeroed out their transit so the angle showed zero for their starting marker. For each marker, each team used the transit to measure the distance and the angle with respect to the starting marker. The direction was determined by observation. The direction was 'left' if the marker being measured was to the left of the starting marker or was 'right' if the marker was to the right of the starting marker. The photo below shows some of the participants working with the surveying equipment.

Once all of the measurements were taken, each team entered their data into a computer program. The program showed a diagram of the markers based on the entered measurements. This diagram was then compared with a diagram provided showing the actual location of the markers. The participants compared the diagrams and decided which markers were inaccurate. They then determined which measurement was incorrect and by how much it was incorrect. Corrections were entered into the program and the new diagram was shown. Although most of the teams had diagrams that were very close to the actual, with just a few small corrections, every team had a perfect match.

3. Working with GPS:

This activity was in the area of Civil Engineering. The activity was performed in teams of two. Each team was provided a Global Positioning System (GPS) unit and a map/photos showing the campus landmarks to enter into the unit. Each pair had to locate each landmark on the Salt Lake Community College campus. For each landmark found, while standing at that landmark, the team was required to store that location into the GPS unit. After all of the landmarks were entered, each team used the GPS unit to show their diagram of entered landmarks. This was compared to the actual diagram to determine the accuracy of their work. Below is a photo of one of the teams entering data into the GPS unit.

4. Building and programming robots:

This activity was in the area of Mechanical Engineering and Computer Science. The activity was performed in teams of two. Each team was provided a Lego robotics building kit, a set of building instructions, a computer and the Lego programming software. Each team initially had the option to build one of four different robots. The robots included a dog, puppy, bug or top-secret robot. For each robot, building instructions were provided. Each of the robots had a characteristic that made it unique, ex. the top-secret robot had sensors to determine when it had hit a wall or reached the edge of a table. The bug walked with long legs that had to be coordinated with each other. The puppy used short bricks for paws that rotated in a vertical direction. The dog used wheels for locomotion but could not turn left or right.

Once the teams had their respective robot completed, each team was taught how to write a program on the computer and download it to their robot. The participants were given instructions on the types of actions that were to be programmed. First they were to write a program to make their robot walk forward and backward then turn left and right. Depending on the robot built, some of the teams found that the design of their robot did not allow their robot to walk backward or turn. Next, each team was to add a touch sensor to their robot and write a program to have their robot turn around when a wall was reached. Next each team was told to add a light sensor and write a program that would allow their robot to follow a line on the floor.

Some of the teams realized that the design of their robot was not appropriate for some of these tasks and decided to start over with a different design. These teams rebuilt robots that allowed turning, for instance, which then allowed them to write a program that would allow their robot to follow a line on the floor, even if it turned or curved.

We noticed that some of the teams were "builders" and spent great amounts of time building more sophisticated designs, which made the required tasks easier. We also observed that other teams were "programmers", using the robot they already built but writing sophisticated computer programs to make their robots do increasingly difficult tasks. We decided that the robotics and programming activity required more assistance from adults; therefore, we had three student helpers on that day rather than just two. Below is a photo of one team building their robot and another working on the computer to write programs to control their robot.

5. Learning the binary numbering system:

This activity was in the area of Computer Science and Mathematics. Part one of this activity was performed as individuals and the second part was performed in teams of two. For part one, each team was provided parts to make a binary/decimal converter. Instructions were provided and a demonstration was shown to make the converter. Each participant followed these instructions to make the converter. When each participant was completed, instructions were given regarding the use of the converter to convert binary numbers to decimal and decimal numbers to binary. In addition, a lecture was given on how to convert hexadecimal numbers to binary and binary numbers to hexadecimal. The participants were given conversion problems and prizes were awarded to participants who could do the conversions correctly. Sample problems are shown below.

1. 1001 1111 from binary to decimal and to hexadecimal

   1001 1111 = ________________ in decimal

   1001 1111 = _________________ in hexadecimal

2. CAFE from hexadecimal to binary then to decimal

   CAFE = ________________ in binary

CAFE = _________________ in decimal

3. 1006 from decimal to binary then to hexadecimal

   1006 = ________________ in binary

   1006 = _________________ in hexadecimal

For part two of this activity, participants worked in pairs. Each pair used the electronic circuit that was built during the first workshop activity. Riddles were provided that were in the form of a question and short answer. Also, a table was provided with all of the capital letters of the alphabet and their respective ASCII values. First, one of the team members would choose a riddle and read the question. The other team member would then be provided with the answer written in ASCII (ones and zeros). That person would set the switches on the circuit to match an ASCII letter in the answer. The letter would be displayed on the seven-segment display and the other participant would write that letter down. This would continue until the pair had decoded the entire answer to the riddle. The team members would then reverse roles so that each had an opportunity to use the electronic circuit to decode a riddle answer.

6. Experimenting with concrete and failure in compression:

This activity was in the area of Civil and Structural Engineering. The activity was performed in teams of four and was completed in two parts. Part one included mixing and pouring a concrete sample. Each team was provided the materials and equipment needed to mix and pour concrete samples. Also, each group was provided a different formula so that a strength comparison could be made of the various samples. Each formula included the same amount of gravel, sand and cement; however, the amount of water was varied for each group.

Part one was performed on the first day of the workshop. Each team was taken separately to the concrete-mixing room. The various elements were weighted (per the formula provided) and placed into the mixer. The mixer was run until the mixture was homogeneous. Prior to pouring the mixture into the sample mold, a slump test was performed. This entailed filling a slump mold one-third of the way and tamping it with a metal rod 25 times to eliminate air pockets. This process was completed three times to completely fill the slump mold. The mold was then pulled up slowly, sliding it off of the packed concrete. The amount that the concrete slumped was measured and recorded.

The concrete was then placed back into the mixer for a final mixing before pouring the sample. The same process was used to fill the sample mold until full. The team number and slump value was written on the cover of the mold and the mold was set aside to dry and cure. The photo included below shows the slump mold and the sample mold as well as two participants ensuring that the sample mold was full before setting it aside to dry and cure.

Part two of this activity took place on the last day of the workshop. Each team located their dried/cured concrete sample and the sample was removed from the mold. The sample was placed into a compression chamber and crushed to determine its strength. The strength of each sample was recorded in a table along with the formula and the slump value. Once all of the samples were compressed, the results were compared. The participants were instructed on how concrete samples can break. Participants were asked to look at each of the samples to make conclusions regarding the strength as it relates to the type of fractures observed. Also, participants were asked to look at the table with the strength and slump data and make conclusions based on the data.

They were then asked to compare the two conclusions. If the two conclusions were divergent, they were asked to conclude why that might be.

D. Post-workshop questionnaire

To help us improve the workshop in future summers, a questionnaire was developed. The questionnaire was written to get input from the participants. The findings were mostly positive. Most participants stated that the presentations were interesting and helpful to understand each activity. All of the participants had a favorite activity with each activity being the favorite of at least one participant. Some suggestions were made for future activities including space activities. Almost 90% of the participants said they would come back for future workshops and/or recommend future workshops to their friends. Some negative comments were made. The two areas where negative comments were made had to do with the starting time being too early and improvement of mid-morning snacks.

Conclusion

Salt Lake Community College planned and held two 1-week summer science workshops for teens, age 12 through 15 during the summer of 2003. One workshop was planned, but, because of the high interest, a second was added. Each workshop was one week long and lasted from 8:00 AM to 12:00 PM. There were 20 participants in each session.

The workshop consisted of six activities, those being: experimenting with concrete, assembling electronic circuits, building and programming robots, working with Global Positioning Systems (GPS), learning the binary numbering system and using surveying equipment. College faculty and administrators as well as lab aides and student helpers participated. The activities were prepared and presented by faculty members that are expert in the activity itself.

Communication with parents/guardians of the participants was taken very seriously. A letter was sent to each parent/guardian prior to the workshop and a notebook containing information about each activity was sent home with the each participant. In addition, an open house was held after the workshop was completed.

All who participated, including the teens, the teens' parents/guardians, and college employees thought the workshops were a great success. Participants and parents/guardians asked to be notified of future workshops. College employees plan to continue to have future such workshops.

Bibliography

[1] Gordon Moore, quoted in the New York Times, 2001

[2] Science & Engineering Indicators—2002 (SEI-2002)

[3] National Science Board, The Science and Engineering Workforce, Realizing America's Potential, 2003

Biography

SHARON DeREAMER

Sharon DeReamer has a B.S. degree in Metallurgical Engineering from University of WI and a M.S. degree in C.S. from University of TX (UTD). For 20 years, she worked as an engineer and computer programmer in companies such as Ford Motor Company, Texas Instruments, and The U.S. Government. For 7 years, she owned and ran a business that taught computers to children. She taught at UTD and currently teaches at SLCC in the CS department.

Dr. NICK M. SAFAI

Professor **Safai** has been the Head of the Engineering Department at SLCC. He received his Ph.D. in Engineering from Princeton University in 1977, and MSE in Aerospace and Mechanical Engineering in 1974, MSE in Civil Engineering in 1975, and MSE in Petroleum Reservoir Engineering in 1975 all from Princeton University. He holds a B.S. in Mechanical Engineering from Michigan in 1972. Prior to joining the academics, Dr. Safai worked in industry, where he served as Director of the Reservoir Engineering Division at Chevron Oil Corporation in California. He has taught both at the graduate and undergraduate levels in engineering science. He has performed research projects for the Department of Energy (DOE), Department of Defense (DOD), National Science Foundation (NSF) and the Oil Industry. He had authored over 45 technical publications in technical journals, government & industry project reports. His research interests include; 3-D multi-phase flow through porous media, wave propagation in filamentary composite materials, stress concentrations, 3-D explicit-implicit finite element, finite difference mathematical modeling of fluid reservoirs, and directional drilling.

He is a member of several engineering societies including American Society of Engineering Education (ASEE). He was elected and has served as the Chair of ASEE Annual Conference Programs for the past four years, a reviewer & session Chair for ASEE for the past 14 years. He is also Chapter Chair for ASCE & a member of ASME.