AC 2011-2426: A K-12 ADVANCED RESEARCH CAMP FOR ENGINEERING AND SCIENCE DISCIPLINES

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Introduction: Science, technology, engineering, and mathematics (STEM) related college degree programs have experienced lower U.S. student enrollment[1] and unwillingness of K-12 students for science and mathematics courses[2]. The enrollment in undergraduate engineering and engineering technology disciplines was down by 16% during the 1986-2006 period[3] and the number of awarded bachelor's degrees in engineering fields fluctuated between 60,000-80,000 during the comparable period[4] in spite of more than 10% projected job growth in engineering disciplines in the near future[5]. Due to their tendency to pursue social sciences and to attend programs at two-year institutions, underrepresented groups such as Hispanics, women or African-Americans have generated even a larger deficit in enrolling STEM disciplines[6]. The current trend in STEM enrollment can partially be mitigated by utilizing effective summer camps.

High school engineering outreach camps have been proven effective to attract as well as to expose students to science and engineering disciplines[7, 8]. A number of camps focused on specific student clusters such as gender [9], grade-level[10] or specific minority groups[7] while offering a number of different engineering subjects. Some other camps focused on specific subjects such as robotics[11] or required a camp fee[12] or minimum grade-point-average (GPA) for camp admission eligibility[13]. In addition to these camps with broad exposure to various engineering fields, research opportunities for high school students have been utilized in engineering outreach. A type of research infusion to high schools was to adopt the university-developed research course template for high school research activities[14]. A summer research experience camp involved junior and senior high school students for only science disciplines but offered a chance to earn one semester hour of college credit and reported to establish a student pipeline for many undergraduate programs nationwide[15]. Another activity offered a six-week residential summer research camp only for sophomores and juniors in high schools, focused on biological, agricultural, environmental, and natural sciences and required a fee and an expectation of a scientific report[16]. Also, a no-fee summer camp offered a variety of engineering research topics in an eight-week session but the camp was restricted to only sophomores and juniors with a minimum grade-point-average of three[17].

In addition to offering a number of K-12 engineering outreach camps[7,8] to attract and retain regional high school students, particularly Hispanics and females, to STEM disciplines by exposing the camp students to a variety of engineering topics, Texas A&M University-Kingsville (TAMUK) developed a new Engineering and Science Frontiers (ESF) summer camp to enhance the K-12 STEM experiences. The ESF camp was a week-long advanced research opportunity on a single engineering or science subject and was aimed towards those high school students who had already attended a previous summer camp at the same institution. The ESF camp overcame some of the high school research camp restrictions such as specific grade levels, minimum GPAs or a camp fee for the underserved minority population of South Texas, a state with a significant underserved minority student population[18]. The end of camp survey verifies the camp outcomes and implies that the research-based outreach camps may have a larger impact on student perspectives of engineering disciplines.

The ESF Camp: The high school day-camp aimed to attract students to STEM disciplines by offering a week-long hands-on advanced research experience for teams of three students on a single subject under close faculty supervision in university laboratories. The camp was sponsored by both Texas Workforce Commission and Texas Higher Education Coordinating Board and was conducted on the TAMUK campus, a Hispanic serving institution with 65% Hispanic population in an under-served region, during July 19-23, 2010. The camp also maintained a website, http://www.engineer.tamuk.edu/esf/index.html, for timely communication on application process and the camp execution. The camp included 33 students from various South Texas high schools involving 13 different school districts, with 25 Hispanics and 25 female participants, and provided a stipend to each student to cover their camp-related expenses such as commuting. Fifteen sophomore students were the largest group in the camp, followed by seven freshmen, six junior, and five senior students. The oldest age group of nine students was seventeen while the number of sixteen and fifteen year old students were twelve each. The participants were divided into eleven 3-student teams and each student was assigned to a project based on their preferences, when possible, to utilize the science and engineering professors as effective high school student mentors.

Recruitment and Enrollment: The camp recruitment was based on invitation-only applications. An invitation letter was mailed to all eligible candidates who already attended previous YESTexas and/or GEMS middle/high school summer camps at the same institution to apply for this camp. The invitation letter explained all the camp features and the application forms contained all the required data fields for both the sponsoring agency reporting purposes and the superior camp execution and satisfaction such as a preferred project ranking. The information on research topics, camp schedule and application was also made available to public on the camp website.

Interested high school students submitted a hard copy of the application package including the application forms, his/her transcript, a school attendance record, and an educational goal statement. Applications were evaluated and ranked by the summer camp leadership team (Dr. Muhittin Yilmaz, Dr. Jianhong Ren, Dr. Carlos Garcia, Dr. David Ramirez, Sheryl Custer) in terms of the ESF camp selection criteria as described in Table 1.

Table 1. The ESF Camp Student Selection Criteria

	Grade Point Average	**Points** (Max. 50 Points)
Core Subject (Science, Math, English & History) GPA	70-79	20
	80-89	35
	90 +	50
Essay (Follow Directions, Organization, Stated Educational Goals, Syntax)	**Number of Elements**	**Points** (Max. 25 Points)
	4 Elements	up to 25 points
	2-3 Elements	up to 15 points
	1 Element	up to 5 points
School Attendance Record	**Attendance**	**Points** (Max. 25 Points)
	0-3 Absences	up to 25 points
	4-6 Absences	up to 15 points
	7 or more Absences	up to 5 points

A total of 33 high school students from regional thirteen independent school districts were admitted to the camp. The school district support on camp participant documentation was very instrumental for the smoother camp admission process.

The Camp Curriculum: A total of eleven engineering and science projects among popular subjects to South Texas population were developed to expose the students to advanced research environment from a number of engineering and science disciplines. The projects also offered maximum hands-on experience opportunity under close faculty supervision and insights about fundamental engineering concepts in daily life items, promoting student enthusiasm for the associated disciplines.

Seven advanced engineering research projects provided student exposure to industrial, chemical, electrical, mechanical, civil, and environmental engineering disciplines, as described below;
Sustainable Manufacturing and Energy Saving Product Design: Sustainable manufacturing is to design and manufacture green products with non-polluting and natural resource conserving processes. The camp students investigated the approaches to evaluate product energy consumption through the whole life cycle by disassembling used cell phones and laptops.
Citrus Waste Conversion to Biofuels and Chemical: Students explored the rudiments of making solid heterogeneous catalysts by impregnation of various noble metal salt solutions onto various catalyst supports, thus creating a "library" of catalysts. Also, the students analyzed diverse samples of treated grapefruit processing waste to determine the total concentration of flavonoids by using a spectrophotometric method. Samples of different particle sizes were analyzed to evaluate the concentration of flavonoids compared to specific standards like hesperitin and naringenin, the main flavonoids of citrus fruits. A GC-MS instrument was used to analyze the specific flavonoids.
Antenna Design for Wireless Communication Systems: Checking e-mails, surfing on the internet with mobile communication devices have become a ritual of our daily life. The students learned the fundamental principles of the antenna systems and investigated the practical performances of a wide range of antenna types and systems.
Programming a Four-wheel Drive Mobile Robot with 4-Degrees of Freedom Robotic Arm: The camp participants became familiar with basic hardware, software and programming techniques and investigated various robotics manipulations. The project resulted in synthesizing optimal algorithms and programs for a number of arbitrary tasks.
Design of a Truss System: The truss is one of the major and most common types of engineering structures. The students designed a balsa wood bridge, assessed a real-world problem and developed at least one feasible solution. Also, the teams conducted research on practical design considerations and integration of the trusses by utilizing project management and teamwork.
Air Quality: A regional research case study helped students to understand the impact of air quality on human health effects. The students conducted experimental research on air emission control technologies and identified the fundamentals of oxidation, absorption and biofiltration control technologies. The case study demonstrated the effects of air pollutants such as ozone, carbon monoxide and particulate matter ($PM_{2.5}$ and PM_{10}) on human respiratory and cardiovascular system. The students also improved air quality by setting up an air emission control laboratory and controlling air pollutant emissions using emerging new air pollution control technologies.

Desalination of Seawater using Gas Hydrates: Gas mixture containing water vapor at high pressure and low temperature form solid crystalline compounds named as gas hydrates that can be applied for the development of a new desalination method. The camp students conducted research on the basics of available desalination processes, investigated the process flow diagrams for a gas hydrate desalination process, and performed the numerical analysis on the amount of energy needed for seawater desalination and comparison with other existing desalination processes.

Four advanced science research projects also provided student exposure to mathematics, geosciences, biology, and computer science disciplines, as described below;
Application of Quaternions to Two-Player Two-Strategy Games: After a basic overview of game theory, the students explored various examples of two-player, two-strategy games, investigated the characteristics of the associated Nash equilibria, covered the special number system, called as Quaternions, during the implementation of usual operations and conducted further research on enlarging the strategic sets of the players.
Impact of in Vivo Ozone in Human Health: Ozone is an air pollutant that may produce concentration-dependent inflammation of peripheral nerves leading to neuropathy in diabetics. The camp students conducted research on the molecular mechanisms underlying sciatic nerve inflammatory damage in diabetes compounded by air pollution exposure.
Global Warming? Let's Get Some Help from the Satellites: The students used a state-of-the-art technology to investigate the satellite data on Antarctic ice sheet. The participants downloaded the satellite data from two different years and monitored the changes in coastal glaciology and glacial feature distributions of the Antarctic ice sheet. Knowledge of the variation of the ice margins along the Antarctic littoral can aid the interpretation of global climate change, particularly global sea level changes, as ice margins are among the first places affected by global climate change. This project monitored the change of ice front employing Satellite imageries and remote sensing techniques.
Enhanced Learning with 3-Dimensional Animation: The camp students conducted research on 3-Dimendional interactive animation techniques, software tools and video game design approaches. Once the students explored the basics of animation concepts, they synthesized their own topic from an engineering field and optimized their own video game by focusing on user-centered, technology-enhanced learning environment.

The Camp Schedule: The five-day camp started at 7:45 am and ended at 5:30 pm each day, which gave a total of 48.75 contact hours, as shown in the detailed camp schedule in Table 2.

Table 2. The ESF Camp Schedule

Time	Monday	Time	Tuesday-Thursday	Time	Friday
7:45	Check in	7:45	Check in	7:45	Check in
8:00	Registration-Orientation	8:00	Research Projects	8:00	Field Trip
9:00	Lab Safety Training				
9:40	Break	9:40	Break		
10:00	Research Projects	10:00	Departmental Introductions		
		10:20	Research Projects		
12:00	Lunch (Guest Speakers)	12:00	Lunch (Guest Speakers)	12:00	Lunch
1:15	Research Projects	1:15	Research Projects	1:15	University Presentations
				2:00	Break
2:40	Break	2:40	Break	2:20	Oral Presentation Competition
3:00	Research Projects	3:00	Research Projects	3:30	Break
4:30	Documentation and Oral Preparations	4:30	Documentation and Oral Preparations	3:50	Oral Presentation Competition
5:20	Daily Evaluation	5:20	Daily Evaluation	5:00	Final Evaluation
5:30	Dismiss	5:30	Dismiss	5:20	Award Ceremony and Dismiss

The camp curriculum focus was on the hands-on project based activities. The participants were trained on important laboratory safety issues and precautions during the *lab safety training*, a prerequisite to conduct research in university laboratories. The students conducted their studies during the *research projects*, where eleven engineering and science projects were investigated in university laboratories under very close faculty and graduate assistant supervision. The *documentation and oral preparations* sessions were utilized for team progress reports and for final oral presentations. A notebook was used to document all research activities and results by each student team, reinforcing teamwork, communication and writing skills. The student teams also prepared their final oral project presentations for the competition on the last day of the camp when many parents/teachers were present. There was a dedicated faculty member, who led the sessions, to explain the notebook, scientific oral presentation as well as judging guidelines to the students and to promptly answer possible questions. During the *oral presentation competition*, each team members orally presented their research activities as well as outcomes and explained the research problem, methodology and results in ten minutes in front of all camp personnel, parents, teachers, and university officials. The oral presentations were judged by well-qualified external faculty and staff members based on predefined judging criteria that included research problem motivation, project description and presentation organization, research conclusions, effective presentation delivery and effective visual aids. The notebook judging was done by the available camp project faculty and graduate assistants based on predefined judging criteria while the students were attending the field trip. The notebook judging criteria focused on documented understanding of the research process, documentations for brainstorming activities as a team, research project execution in a given timeline, data analysis with appropriate analytical and mathematical skills and overall organization in terms of neatness as well as clarity. Although the teams were told about the notebook and oral presentation competitions at the beginning of the camp, they were not told about the weight of each competition to ensure best team preparations for both competitions. During the competition break, a number of parents shared their very favorable camp thoughts about the effects of the camp on their children in short oral testimonials in front of all award ceremony attendees.

The camp included a number of sessions to ensure smooth execution and to enhance camp outcome achievement. The *check-in* of the camp participants by the camp coordinator was done in the morning and the camp chaperones guided the students to reach their upcoming activity. The camp coordinator and the chaperones shadowed the students at all times. The *registration-orientation* session provided the camp essentials such as important camp policies, documentation materials and name badges, introduced the camp leaders, coordinators, chaperones, faculty, and graduate assistants, and included a brief speech about the importance of STEM disciplines and camp outcomes. The *break* sessions gathered all participants together in a hall with continuous chaperone supervision, light refreshments and student resting opportunity. Professional engineers and scientists from regional representative industries (Mr. Naim Khan – the Kingsville city engineer, Mr. Rene Ramirez – Flint Hills of Corpus Christi, Mr. Robert Guerrero – El Paso Productions) as well as undergraduate/graduate students from electrical, environmental, and chemical engineering disciplines and a former campus queen were invited during the *luncheons* to address the camp participants on engineering and science career options as well as to promote the camp outcomes such as presenting viable role models for prospective engineering students. Written *daily evaluations* by the camp participants provided timely feedback on the outcomes of the camp learning experiences and activities. Adjustments, if needed, were made on the next day to ensure the expected camp outcomes. During the *departmental introductions*, six engineering and science department representatives from mechanical, chemical, civil, environmental, biology, and industrial technology disciplines presented their programs to the camp participants in ten-minute interactive sessions by focusing on the nature, admission and scholarship opportunities, and career perspectives of their respective disciplines. The port of Corpus Christi industrial facility *field trip* on the last day of the camp offered insights about practical engineering career opportunities, existing facilities and daily practices of as well as extensive interactions with professional engineers. The TAMUK *university presentations* on housing, financial aid, and admission process prepared the students, parents, and guardians for college life on the last day of the camp by offering detailed perspectives, available local, state and federal scholarship as well as financial aid opportunities and critical Texas university application process and campus housing options. The camp participants completed the written *final evaluations* that contained the required questions for the sponsoring agencies as well as the camp leadership questions to identify the impact and the outcomes of the camp. The *award ceremony* included the first, second, third, and honorable mention team award presentations by the Dean of Frank H. Dotterweich College of Engineering. High school representatives (HSR) such as counselors, principals, and science teachers, all industry professional speakers and student parents were invited to the lunch on the final day of the camp for informal discussions on engineering and science careers and to all afternoon activities.

The Camp Evaluations: The camp students completed the daily and the final camp surveys. As the daily surveys indicated the smooth camp execution and student satisfaction, the final survey contained questions to identify pre-camp attitudes as well as post-camp student perspectives and strengthened the conclusions of the camp goal achievements for STEM outreach as well as institutional recruitment efforts. In addition, the camp leadership observations, the research project faculty and graduate assistant reviews, the documentation session faculty member evaluations and parent oral testimonials during the competition breaks about the effects of the camp on their children further validated the positive outcomes of the camp.

The daily surveys focused on the camp execution performance such as the most and least meaningful student experiences, possible improvements for the camp and suggestions for future camps. All participant comments were promptly reviewed by the camp leader and were responded accordingly such as ensuring promptness of each camp activity or explaining the camp policies for best experiences.

The week-long research camp can be concluded as an effective outreach program. Based on the final survey, 23 students stated that they would like to pursue a degree in engineering because of their participation in the summer camp, indicating the success of the camp to motivate the students to engineering fields. Also, 29 out of 33 students rated the ‘My participation in ESF increased my confidence in my choice of major’ as ‘Agree’ or ‘Strongly Agree’. A number of camp students approached to TAMUK faculty from several STEM disciplines for possible future collaboration opportunities such as laboratory assistantship during the school year or enrollment in summer courses. Also, the professional engineers were asked to present their company STEM discipline-specific employment and career perspectives. In addition, 25 participants rated the ESF camp ‘the most effective’ with respect to the other two university outreach camps, suggested by 9 participants each, and 24 students indicated ‘one-week’ as the best ESF camp duration.

The camp has illustrated several institutional benefits. When students were asked about their college choices before participating in the ESF camp, only 10 students indicated their plans to attend TAMUK. On the other hand, 23 students developed plans to attend TAMUK since their participation in the ESF camp, i.e., 130% increase between pre- and post-camp institutional interest, indicating the performance of the university recruitment efforts. The helpfulness ratings of the TAMUK housing, admission, and financial aid presentations were all ‘Agree’ or ‘Strongly Agree’ while 24 out of 33 stated that the professional speakers provided useful information by rating ‘Agree’ or higher. A lot of students and their parents further discussed their specific college preparation questions after the award ceremony or made appointments with the three TAMUK offices.

The final survey also revealed information about the student expectations and status. When the participants were asked about their motivations for the ESF camp, 29 of 33 students stated ‘the educational experience’, 25 of 33 students stated ‘the opportunity for hands-on research’, and ‘the stipend’ was the third factor indicated by 18 students. Moreover, 14 of 33 students expressed their qualifications for free or reduced lunch during 2009-2010 school year and 28 out of 33 expect to graduate under "distinguished" plan from their high schools. In addition, the biggest hindrance to attend college was said to be financial obstacles, as stated by 20 students. The underlying results suggest the extent of student willingness and the biggest obstacles in under-served regions towards STEM educational and research opportunities. Also, 32 out of 33 students stated that English is the primary language spoken at home, implying an already-established communication path.

The team competition performances, final survey data and insightful STEM career inquiries suggest that essential skills and student engineering perspectives have been improved during the camp. The research project notebook preparation and oral preparation/presentation reinforced teamwork, communication and writing skills of the camp participants, as indicated by the superior competition scores. The camp students favorably verified the improvements on oral presentation (25 out of 33), teamwork (29 out of 33) and documentation skills (23 out of 33) while writing skills ranked the last (12 out of 33). Moreover, the teammates are most effective to improve the 'teamwork' skills of the team members, as rated by 30 students, followed by the 'documentation', as rated by 18 students, and 'oral presentation' skills, as rated by 16 students. The educational and informative aspects of the field trip were verified by 'Agree' rating by 16 students and 'Strongly Agree' rating by 10 students while "The field trip to the Port of Corpus Christi steered my interest toward and enhanced my understanding of the engineering field" received 11 'Strongly Agree' and 13 'Agree' ratings from the camp participants. Through field trip, luncheon discussions with professional engineers, and extensive interactions with TAMUK faculty members, students were able to explore interests in various engineering fields and apply research strategies and fundamental engineering concepts to daily life items.

The student short answers to open-ended questions suggested important conclusions about different camp components; a) the 'What did you like best about ESF?' question indicated that around ten students liked most the hands-on research experience during the ESF camp while the remaining students expressed different factors such as learning new software, professor and graduate assistant involvement; b) a lack of time for project documentation as well as oral preparation and long camp days appeared to be the ESF camp least liked components, as suggested in responses to the 'What did you like least about the ESF Camp?' question; c) shorter days and longer time for preparations were among the most suggested items to improve the future ESF camp among others such as fewer number of speakers or more projects, as concluded by the answers to the 'What do you suggest to improve the future ESF summer camps? (Suggestions for new projects, camp execution, etc.)' question; d) the successful team requirements contain teamwork and communication skills, due to the answers of the 'Based on your team performance, what do you feel are the required skills for a successful team' question; e) evaluating the responses to the 'Based on the oral presentations, what was the most appealing ESF project attracted you to engineering and science?' question, the design of a truss system was seen to be the most appealing ESF project; f) according to the 'What engineering disciplines and/or projects would be the most appealing to "South Texas" students?' question results, the most appealing projects to South Texas students are suggested to be petroleum from chemical and robotics from electrical/mechanical engineering disciplines; g) the 'Who have been the three most important people who motivate you to engineering fields? How?' question indicated that the three most important people who motivate high school students to engineering fields span a very wide range including parental members, camp faculty and graduate students; and, h) when the students responded to the ‘Can you state a unique ESF camp feature different than other usual summer camps?’ question, one activity for the whole week seemed to be the unique feature of the ESF camp, among many other ideas such as perfection, using college equipments and hands-on experience.

Some of the camp students expressed their satisfaction with the camp in their testimonials, such as “ESF helped me figure out what type of Engineer I wanted to become. The projects were challenging and I enjoyed them. This camp encouraged me to challenge myself future”, “ESF has increased my interest in engineering, and gave me more knowledge about it. I also got to learn a lot about what it means to work on a research project. It was an overall good experience”, “It has helped me get a real college experience. I loved the hands on experience.”, “If you have the chance to come to this camp take it. There is so much hands-on experience and it strongly guided me into my engineering career choice!”

Conclusions: The high school advanced research outreach camp effectiveness has been illustrated by the final survey data and positive student attitudes. The camps with broad hands-on exposure to various engineering fields in shorter durations and the camps with a focus on a single research subject appear to complement each other to enhance student understanding of STEM related career opportunities and prospects.

Novel pedagogical approaches in STEM outreach programs and residential camp benefits as well as constraints will be evaluated for the future camps. Also, institutional enrollment mechanisms and data access protocols will be explored to systematically monitor the camp student attendance in a STEM discipline at TAMUK or other universities.

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