Reflections on Eight Years of Undergraduate Research at Our Community College

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Klaus Bartels is an Adjunct Faculty member at San Antonio College (SAC) in the Mathematics, Architecture, Physics and Engineering Dept. He was born near Buenos Aires, Argentina and immigrated to the U.S. in 1956. He grew up and went to college in the Boston, MA area. He has a B.S.E.E. from Tufts University (1972) and an M.S.E.E. from M.I.T. (1975). He served as a Communications-Electronics Engineer/Officer in the USAF from 1975 to 1999, retiring as a colonel. He worked part time as a Flight Director at the Challenger Learning Center of San Antonio from 2000 to 2009, and has been teaching remedial math and engineering classes at SAC since 2000. He has also been involved in various engineering summer programs at SAC, including instructor for Robotics Camps for 3rd to 5th graders (2012 - 2014), instructor and coordinator for the Early Development of General Engineering program for high school students (2007 - 2015), and faculty adviser for alternative energy Summer Undergraduate Research Programs (2011 - present). In addition, he is currently the SAC Co-PI for the 3-year NSF CIMA-LSAMP Alliance grant supporting increased representation of Underrepresented Minorities (URMs) in STEM education and undergraduate research.

Ms. Dee Dixon

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Abstract

Since 2010, San Antonio College (SAC) has been the center of a continuously increasing family of undergraduate research projects hosted by Texas' first Math, Engineering, and Science Achievement (MESA) Center. A paper presented at the 2012 ASEE Conference in San Antonio described the start of this program at this community college. It has been widely reported that undergraduate research programs at four-year institutions increase retention, improve students' success, and produce higher quality graduates. Results demonstrate that two-year institutions can also initiate and maintain successful undergraduate research programs. This paper presents the evolution of the undergraduate research program started at SAC in 2010 as a summer-only activity into a year-round program. It also describes benefits and limitations, offers advice for starting a research program at community colleges, and outlines future plans.

Background

Undergraduate research programs have proven to be powerful tools that provide major benefits for science, technology, engineering and mathematics (STEM) education such as increased retention, facilitating learning of complex subjects, and providing students with life-long study and research skills. Numerous studies describe the benefits of undergraduate research programs and their outcomes for STEM undergraduates, providing information that can be used to build strong engineering programs [1] – [6].

Literature Review

The benefits from these activities reach a multitude of stakeholders. For students, the benefits include improved academic persistence and increased interest in pursuit of graduate education. These activities also foster broad development in areas that include communications and technical skills, understanding the research process, ability and confidence to conduct research, motivation to learn, and ability to work in teams as well as independently. These effects are also seen as strong motivating elements for underrepresented minority student populations that are experiencing greater gains than others participating in undergraduate research [7] – [10].

MESA Center Establishment

Since inception in 1970, MESA has been instrumental in helping educationally disadvantaged students to excel academically and obtain STEM degrees [11] – [15]. When SAC's MESA Center opened in 2007, it was the first in Texas [16], [17]. Since then, MESA memberships and student participation has grown steadily. Students have developed extended social support networks through the STEM-focused clubs like Mexican American Engineers and Scientists-Latinos in Science and Engineering (MAES), Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS), Society of Women Engineers (SWE) and Society of Physics Students (SPS). In the academic year 2009-2010, 368 students made 3,563 visits to the center, while in 2010-2011, 454 students made 4,525 visits to the center, amounting to increases of 23% and 27% respectively. In 2018, the overall participation was 668 students.

Activities sponsored by the MESA Center

Engaging students in STEM-related activities is critical to retention because it leads to professional mentoring relationships. These activities include undergraduate research, field trips, conferences, guest speakers, orientations and outreach events. Faculty play a critical role in these activities. One of them meets weekly with SPS students for "Fun with Physics Fridays" where students engage in activities that include training to operate telescopes at the 22,000 square-foot Scobee Education Center, which is a first-of-its-kind, next generation Challenger Learning Center with a planetarium and rooftop star deck and observatory. Students volunteer to operate the telescopes for the public on Friday nights. The professional development workshops include resume writing, creating a LinkedIn profile, club officers' retreat, e-portfolios, scholarship essays, transfer tips and research paper sessions. In 2017, 98 students participated in these workshops; in 2018, 94 students participated. Because families think the students spend an inordinate amount of time at the MESA Center, Family Night was implemented to share some of the projects in a fun, engaging and interactive environment. Another highlight for 2018 was the center's visit by Congressman Joaquin Castro, who wanted to learn more about the undergraduate research project, specifically the hydrogen fuel cell vehicle.

SAC Undergraduate Research Project Data

The undergraduate research program at SAC has grown almost 300% since 2010 as shown in Figure 1 and Table 1. In 2010, three teams and a total of 10 students performed research. By

2018, there were eight teams and 38 students involved. The increase in participation can be credited to the various National Science Foundation (NSF) and U.S. Department of Education (USDOE) grants that have been awarded to the college in an effort to increase the number of underrepresented minorities pursuing STEM. A particular area of growth occurred between 2014 and 2017 where there was a focused effort to boost summer undergraduate research. The number of teams increased from three to seven and the number of student participants increased from 10 in 2014 to 40 in 2017. The number of underrepresented minorities increased from seven students in 2014 to 36 students in 2017, a 414% increase. Also, the number of female students doing undergraduate research projects increased from four in summer 2014 to 17 students in 2017.

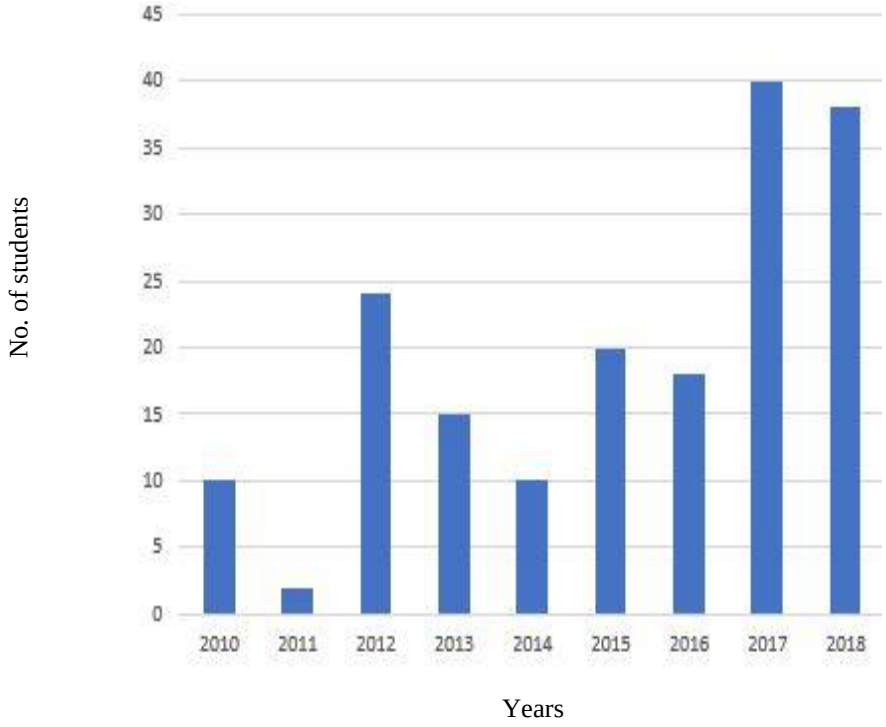

Figure 1 - Students in undergraduate Research Projects at SAC

In addition, the number of active members in the SAC section of the SWE grew from five to 20, many of them involved in research. In fact, SWE members took ownership of a hydroponics project, which along with the hydrogen fuel cell vehicle project and one investigating a possible meteorite impact site, have evolved into year-round research efforts. This paper will highlight these and a few other significant research projects.

Item	Year	# Student	Project Title	# Faculty
1	2010	3	hydroponics	1
2	2010	4	exercise bike	1
3	2010	3	PV panel efficiency	1
4	2011	2	Summer Solar Undergrad Research Pgm	2
5	2012	4	Solar Day Extension	2
6	2012	4	Recirculated Water Cooling	2
7	2012	3	Intermittent Mist Cooling	2
8	2012	7	Recirculated Water Cooled PV Solar Module	2
9	2012	6	Hybrid Photovoltaic System	2
10	2013	4	Electrical Subsystem for Solar Panel Electric Cart	1
11	2013	4	Vibration of Fluid Stream in Microgravity	1
12	2013	4	Gyroscopic Orientation in Microgravity	1
13	2013	3	Determing the Extent of Geological Formations Based on Surface Vegetation and Topsoil	1
14	2014	4	Small Scale Field Testing of Seismic Mesh	1
15	2014	3	XXXXXXXXX Structure: Reexamination of Positive Impact Site Identification	1
16	2014	3	Roll With It: A Portable, Detachable Motor for a Manual Wheelchair	1
17	2015	4	XXXXXXXXX Structure Possible Impact Site Investigation	1
18	2015	4	Geology of the XXXXXXXXXXXX Formation in XXXXXXXXX	1
19	2015	4	Creating the MIG: A Modern Multi-Hydroponic Indoor	1
20	2015	4	SolGo ARV: Electrical System	1
21	2015	4	SolGo ARV: Mechanical System	1
22	2016	4	Solar Electric Cart Performance	1
23	2016	3	Solar Tree	1
24	2016	3	Hydroponics Monitoring Vehicles	2
25	2016	3	HFCV - Electrical System Performance	1
26	2016	5	XXXXXXXXX Impact Study	1
27	2017	19	2017 Prototype Hydrogen Fuel Cell Vehicle	3
28	2017	5	Sonar Imaging in an Unmanned Underwater Vehicle	1
29	2017	4	Automation and Control of Hydroponic Systems	1
30	2017	3	Quantified Yield of Deep Water vs Ebb and Flow	1
31	2017	3	XXXXXXXXX Structure Gravitational Anomaly	1
32	2017	3	Environmental Impact Survey of XXXXXXXXXXX	1
33	2017	3	Effects of Three Light Treatments on Basil and Radish	1
34	2018	7	Farming Automation	1
35	2018	2	Wing-raising Display Behavior in White-winged Dove	1
36	2018	11	2018 Prototype Hydrogen Fuel Cell Vehicle	4
37	2018	4	Optimization of HFCV Electrical Subsystem	1
38	2018	3	XXXXXXXXX Structure Gravitational Anomaly	1
39	2018	2	XXXXXXXXX Probable Impact Site	1
40	2018	5	Vertical Hydroponic System - Nutrient Film Technology	1
41	2018	4	Programming for Hydroponic Automation Systems	1
Total Students:		177		

Table 1 – SAC Undergraduate Research Projects (2010 – 2018)

SAC Undergraduate Research Program Evolution

Early Years (2010 – 2012)

In 2010, our college collaborated with our local four-year public university to submit and jointly manage a CIPAIR NASA grant to improve the engineering curricula at both institutions by having new or existing courses infused with NASA-related materials. The program was described in a paper presented at the 2012 ASEE Annual Conference in San Antonio [1].

The program was developed with two components. One was the standard internship in which NASA accepted four students and one faculty member for a 10-week period to do research at the Johnson Space Center in Houston [18] – [21]. The other part was the development of an undergraduate research plan that would help SAC students relate their NASA-sponsored research with STEM course content and classroom activities. Ten students were accepted to do undergraduate research at SAC with two faculty members.

The 10 students formed three teams and each team submitted a research proposal. One team selected a subject that might be helpful to future lunar farming: hydroponics. They designed and built racks, containers, and an irrigation system in a campus greenhouse. The students planted several types of vegetables and monitored their evolution with respect to different feeding formulas and growing conditions. This project was followed by several other hydroponics projects over the last eight years. A second team of students designed and built a stationary bicycle exercise machine to monitor the energy output of riders in three different pedaling positions. The third team studied how temperature affects the output of photovoltaic (PV) solar panels [22]. This led to additional solar projects from summer 2011 to summer 2012, involving 26 students and six research projects [23] – [28]. The primary purpose of these studies was to investigate different methods for cooling the surface of solar PV modules ("panels") and their impact on module power/efficiency. The cooling methods employed included forced air, intermittent water mist, continuous water mist, and continuous recirculated water.

Mid-Years (2013 – 2015)

NASA Reduced Gravity Research Projects [29]

Two teams of four SAC students and two faculty advisors were accepted by NASA Johnson Space Center's Ellington Field in Houston to conduct experiments aboard the reduced gravity

aircraft in November 2013. The two SAC teams were selected under the Minority University Research and Education Program (MUREP) flight program based on scientific merit and educational outreach potential. The Reduced Gravity Education Flight Program (RGEFP) gives undergraduate students the opportunity to design, build and fly experiments in reduced gravity working with NASA scientists and engineers to develop experiments based on current NASA research. Students and their NASA mentors perform these experiments aboard a microgravity aircraft which produces periods of weightlessness for up to 25 seconds at a time by executing a series of approximately 30 roller coaster-like parabolic flight paths over the Gulf of Mexico. The program included training, ground testing, calibration, safety approval, and in-flight testing. One experiment provided new information about the behavior of a fluid stream undergoing periodic vibration changes in microgravity conditions [30], and the other provided a proof-of-concept for a gyroscopic orientation system to stabilize spacecraft reentering Earth's atmosphere [31]. Following the flights, the teams evaluated their findings, drew conclusions and provided the results in their final reports to NASA.

Bee Bluff Possible Meteorite Impact Site

At times, undergraduate research projects are an extension of a faculty member's thesis. Such is the case for a project referred to locally as Bee Bluff, which began in the summer of 2014 [32]. The Bee Bluff area is near Uvalde, Texas, about 90 miles west of San Antonio. In the 1970s, Geologist William F. Wilson discovered some anomalies that suggested a possible meteorite impact site. Initially, the SAC research team performed elevation measurements and collected rock samples along the Nueces River [33]. The following year a gravimeter was used to measure the gravity loads in an area that is mostly flat farmlands with no physical signs of a crater. In fall 2017, this became a year-round project. The teams focused on locating the central uplift of the site where the soil would have rebounded after the initial impact millions of years ago. The team is finally getting data indicating the rim of the central uplift [34], [35]. The students' research has started to gain the attention of others. In December 2017, some students gave a presentation to the community at El Progreso Memorial Library. In the Summer of 2018, a reporter and photographer from the San Antonio Express-News chronicled the students in the field [36]. If the students research determines that Bee Bluff is indeed a meteorite impact site, this body of research will be added to the Earth Impact Database maintained by the Planetary Space Science Center in Canada, which currently lists 190 known impact sites worldwide. [37]

Solar Electric Cart

From Summer 2013 to Spring 2016, 16 students completed four research projects involving the design, construction, and testing of a solar electric cart [38] – [41]. These students successfully converted an old, worn-out gas utility cart into a fully-functioning solar-electric vehicle. SAC's MESA Center has used the vehicle at various school events to increase students' interest in STEM education and careers as well as promote sustainability and renewable energy technology.

Later Years (2016 – 2018)

Hydrogen Fuel Cell Vehicle (HFCV)

From Fall 2015 to Spring 2018, 30 SAC Motorsport (SMS) team students completed four projects involving research, design, construction, and testing of prototype hydrogen fuel cell vehicles to compete in the Shell Eco-marathon Americas fuel efficiency competition [42] – [45].

Figures 2 & 3 – [redacted] Motorsport teams at 2017 and 2018 Shell Eco-marathon

Shell Eco-marathon challenges student teams worldwide to design, build, test, and compete with ultra-energy-efficient vehicles. In April 2017, SMS, comprised of 13 students and four faculty/staff advisors, competed in the Shell Eco-marathon Americas event in Detroit. This international event drew 120 high school and college teams and over 1,200 students competing in five different categories covering both prototype vehicles and urban concept vehicles. The fuel efficiency of SAC's vehicle was the equivalent of 829.4 miles per gallon of gasoline (mpge), garnering 3rd place in the hydrogen fuel cell prototype category. A new 2018 SMS team of 11 students built a new, more fuel-efficient HFCV focusing on reducing vehicle weight and drag. As a result, the 2018 vehicle was 81 pounds lighter with a more aerodynamic body. The April 2018 Shell Eco-marathon competition in Sonoma, CA included 100 high school/college/university

teams from North, Central and South America. SAC was the only U.S. community college competing. The 2018 HFCV achieved 945 mpge, a 14% increase over 2017. The vehicle placed fourth out of nine teams in fuel efficiency in the hydrogen prototype category. In addition, the team's attractive, ergonomic, and aerodynamic vehicle design placed first out of 67 teams in the prototype design competition. Based on knowledge gained since inception of the project, the 2019 SMS team is designing and building an even lighter and more efficient HFCV for the competition in April 2019. This marquee undergraduate research project has provided students with research and teamwork skills, as well as hands-on engineering-related experience. Also, students have taken the HFCV to many STEM-related events at SAC and in the community to promote sustainability and energy efficiency, as well as increasing students' interest in STEM careers.

Unmanned Underwater Vehicle

In Summer 2017, five students designed, built, and tested a prototype remote-controlled unmanned underwater vehicle (UUV) for use in locating targets in bodies of clear or turbid water [46]. A sonar device and video camera were mounted to the vehicle to provide imaging feedback to the operator. Microcontrollers were used to control vehicle operation. The UUV was successfully tested in bodies of water down to a depth of 20 feet in collaboration with local emergency management personnel/divers (Figure 4 a-b-c). The project served as a proof of concept for possible future upgrades that would culminate in a fully operational UUV that could improve the responsiveness and safety of emergency underwater search operations.

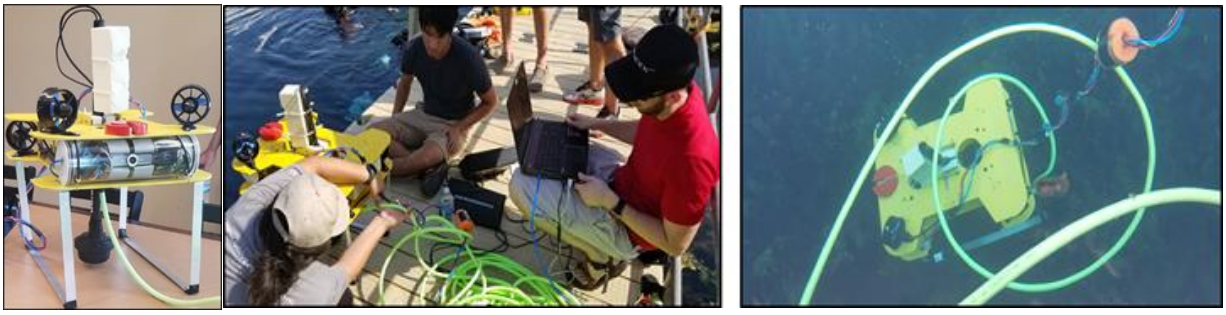

Figure 4 a-b-c – Remote-Controlled Unmanned Underwater Vehicle

Hydroponics Projects

Increased interest in shifting food production to urban areas and closer to final consumers contributed to a funding stream of over six years for student research related to hydroponics and food production automation at SAC. Initial funding for the design and construction of hydroponic

systems stemmed from the USDOE Re-Energize sub-grant administered by Texas State University (TxState) [47]. The innovation shown by our community college students led TxState to submit a successful U.S. Department of Agriculture (USDA) proposal under which students there would combine forces with sub-grantee students at SAC to advance their hydroponic systems research. That grant provides funding for materials, outreach and stipends. It challenges SAC's students to improve upon turnkey systems using lower-cost materials and advanced automation. Ongoing research projects encompass comparative system analysis, lighting studies, automation design and nutrient studies. The two primary thrusts of SAC's hydroponics projects from 2016 to 2018 were intensification and automation of urban food production. Crops can be grown in "stories" in order to maximize vertical space and minimize land occupation [48]. Students are intensifying food production by designing and assembling hydropic systems that will operate in a shipping container and other structures where we can control ambient conditions. Multiple grant funds have provided student stipends and scholarships in recent years. These include the USDOE Re-Energize and USDA EverGreen sub-grants under TxState as well as the USDOE Title III Tenaces grant. The critical shortage of farm labor in the United States creates a pressing need for automation systems that reduce the requirement for human intervention in the production of food crops. During Summer 2016, the first student experimentation with programmable automation led to the design of a mobile device that supported hydroponic instrumentation. In Summer 2017, students completed the first stage of an automated hydroponic system using Arduino programmable devices linked to instruments capable of reading the pH level, nutrient level, CO_2 level and ambient temperature in a hydroponic system. As needed, the programmed devices would trigger pumps and other mechanisms to adjust any factor that moved out of the target range for optimal plant growth [49]. USDA funds the team leads through the EverGreen sub-grant and also links SAC to sister institutions where students engage in similar projects. The powerful cross-pollination of ideas coupled with the sharing of technology enriches the learning experience for all students involved.

Funding, Support, Collaborations, and Partnerships

The MESA Center and undergraduate research program would not exist without funding from NSF and USDOE grants. The center has been supported by seven grants over the years. The grants include Minority Science and Engineering Improvement Program (MSEIP), which was a USDOE grant that provided staff for the center and supported a summer pre-engineering bridge

program for 9-12 grade students; Adelante Tejas, which was a $5.5 million USDOE grant that was a partnership with Sul Ross State University that served underrepresented students in STEM through activities aimed at boosting enrollment, retention, transfer and ultimately graduation; Exitos, which is $3.13 million five-year USDOE Title V cooperative grant with Our Lady of the Lake University that has a goal of developing Hispanic Serving Institutions by building institutional capacity and supporting sustainable programming like the undergraduate research program while promoting STEM majors; and the Re-Energize grant, which was a USDOE grant that was a partnership with Texas State University and other community colleges that promoted activities and research in "green" energy systems and sustainability.

Currently, the center is supported by four grants:

- ***Tenaces*** is a $3.8 million USDOE Title III grant focused on increasing STEM majors at SAC and improving student persistence. A significant amount of funding provides undergraduate research opportunities. (*USDOE Award # 31C160108, directed by Dr. Barbara Knotts.)*
- ***Puentes*** is a five-year $2.63 million USDOE Title V Hispanic Serving Institutions grant that supports sustainable programming and building institutional capacity, which includes undergraduate research. (*USDOE Award # 031S150129*, directed by Patricia Medina.)
- ***Motivating Engineers to Achieve*** is an NSF grant that provides engineering scholarships and supporting student activities. (NSF Award # 1356666, directed by Dr. Dan Dimitriu.)
- ***Ciencia, Ingenieria y Matematicas Aliados*** (CIMA) LSAMP is an NSF grant that funds peer mentors, tutors, STEM-focused activities and undergraduate research. (NSF Award # 1712626, directed by George Johnson of St. Philip's College.)

The college has had two different NSF grants aimed at providing scholarships to STEM students. The first evolution was called the Mathematics, Engineering and Technology Awards (META) that awarded scholarships to students based on financial need. These were awarded to students who had any declared STEM major. In 2010, 50 scholarships were awarded. In 2011, 60 scholarships were awarded. In 2012, 43 scholarships were awarded. Over the course of the grant, there were a total of 55 graduates. The second generation called Motivating Engineers to Achieve (META) helped engineering students persist. In 2015, there were 35 students who received a scholarship and 11 graduates that year. In 2016, there were 40 students who received scholarships

and 11 graduates. In 2017, 23 scholarships were awarded, and nine students graduated. In 2018, nine scholarships were awarded and there were no graduates.

From 2015 to 2017, the Re-Energize Renewable Energy program funded some research projects. The grant aimed to improve recruitment and retention of STEM students through renewable energy research and education partnership between Texas State and five minority serving institutions, including SAC. Funding for Re-Energize was provided by a grant from MSEIP. Throughout the three-year Re-Energize program the collaboration between SAC and Texas State resulted in strengthening our capacity to use renewable energy technologies and activities to increase recruitment and retention of students, especially underrepresented minorities, in STEM at SAC.

The CIMA-LSAMP grant, which is comprised of all five Alamo Colleges: San Antonio College, Palo Alto College, Northeast Lakeview College, and Northwest Vista College and the lead institution is St. Philip's College, funded several projects since 2014. Its mission is to significantly increase the number of underrepresented students who attain bachelor's degrees in STEM.

Adelante Tejas and a previous evolution of Puentes helped with brick and mortar by converting four classrooms into the MESA Center and adjoining workshop where students work on academic and undergraduate research projects. Over the years, the activities have outgrown the space. The center and the rest of the building it is housed in will undergo a major renovation through a $450 million bond package for the Alamo Colleges District. Of that, $83 million will make capital improvements at San Antonio College.

Establishing a college-going culture and promoting STEM was an integral part of MSEIP, which funded the Early Development of General Engineering (EDGE) from 2011 to 2015. The summer camp program taught mathematics, engineering and robotics to high school students. It started with an NSF discretionary grant in 2003 [50] and served over 300 students with a steady participation of underrepresented minorities, including females [51]. Some current MESA members came through the EDGE program, which they credit for choosing to attend our engineering program at SAC.

Faculty/Student buy in

Faculty are engaged in a myriad of ways through the various grants the college has on campus. Each of the grant directors/grant writers work collaboratively to propel engagement and leverage dollars. One of the ways faculty first get engaged is through a STEM Faculty Institute that is held

each summer by the director of one of our USDOE Title III grants. At the institute, faculty learn about best practices and current activities ongoing on campus. Other ways we get faculty engagement is from their colleagues. Often, faculty members reach out to their peers who might be interested in leading a project with students. At the community college level there is not much opportunity to perform research, and through the undergraduate research program faculty have a chance to engage in such activities.

Students are encouraged to participate in the undergraduate research program from their peers. Usually, former research participants are called on to give presentations on their individual experience to students who have expressed an interest in research. Often, students opt to get engaged because it is a chance for them go get hands-on experience, expand their knowledge, contribute to a project and build their resume. Some former students truly use the experience to catapult themselves and other students see the impact research can have on their academic and career pursuits.

For example, the college has had a number of students participate in undergraduate research, which helped them to land at prestigious institutions like the Colorado School of Mines. One of our students, who had participated in summer research through a partnership with a local four-year institution, was selected by Northern Illinois University to research the impact tourism had on the water quality in the Yucatan Peninsula. This student was interested in this body of research because she was raised in Mexico with grandparents who lived in a village that did not have access to clean water. This student, who encouraged her younger sister to follow her path, is now completing her education at UTSA, where she continues to get involved in research and sustainability projects. Another female student came to the college as a non-traditional student. She was first introduced to campus through our Women's Empowerment Center. From there, she was encouraged to get involved with the MESA Center and the undergraduate research program. The focus of the USDOE Title V grant at the time was to restart the college's geology program. This student participated in several undergraduate research projects before taking advantage of a newly formed 2+2 transfer agreement with Sul Ross State University. The student graduated from Sul Ross and is currently applying to graduate school. Aside from landing other research opportunities, some of our students land competitive internships. That is what happened to a female student who attended a STEM conference a few years ago. She had been on the hydrogen fuel cell vehicle team and then lead the unmanned underwater vehicle research team. The

recruiters at the career fair were so impressed with the student's resume that she was offered a summer internship on the spot. That experience last year propelled and prepared this student for a more prestigious summer internship with the U.S. Department of Defense this summer. All of these experiences helped this student to ultimately decide her major —mechatronics, which she is pursuing at a four-year institution. Many of our students work part-time jobs in the service industry while going to school. But increasingly, students who participate in undergraduate research gain an additional set of skills that local employers want. The team leader of last year's hydrogen fuel cell vehicle team was working part time as a tire installer at a local retailer while attending school fulltime. Last semester, a local employer reached out to the college in search of a student with particular skills. She was the only student that met the requirements and was selected for a temporary internship, which was made into a full time permanent position due to her outstanding performance.

Sustainability

The undergraduate research program at San Antonio College benefits from federal grants that help support it with equipment purchases, travel expenditures, student stipends and special pay for faculty. It also benefits from partnerships the college is developing with local companies that provide resources as project needs demand. The college and community are committed to the continuation of our research program, such that if grant funding were not available other sources of funding would be found. An example of a school funding resource not tied to grants is the Office of Student Life Student Activity Funds. They were used to support the hydrogen fuel cell vehicle team's travel to California this year. Another non-grant resource is the Alamo Colleges Foundation, where private individuals and businesses have donated funds to support the hydrogen fuel cell vehicle research project.

Awards & Recognition

SAC faculty and students have received many awards and much recognition for its remarkably successful in-house research program. Just a few examples are described here. Our lead engineering faculty received the 2015 Presidential Award for Excellence in Science, Math, and Engineering Mentorship. SAC also received three mentor/mentee awards by TxState under the 3-year Re-Energize program. Students who designed and built the solar electric cart were recognized when the vehicle was showcased at SAC's 90th anniversary gala. In addition,

participation in research projects at SAC has been instrumental in students obtaining highly competitive internships and research opportunities at other institutions. A recent example includes a student winning an award for her research at a national HENAAC conference and then landing an internship with Northrop Grumman.

Limitations for Faculty Advisors, Mentors, and Students Involved in Research Projects

At community colleges, faculty are often not paid for supervising research projects. Some grants have funds to compensate faculty advisors. However, full time faculty do not receive reduced teaching load for participating in research activities. Community college faculty also do not have graduate students and post docs to assist with supervising research projects. Community college faculty are focused on teaching and are not encouraged to be involved in research activities. Also, community colleges have limited facilities (i.e., labs and workshops) for research. Some student limitations include weaknesses in soft skills such as time management, communications, and teamwork. At times, this results in students dropping out of projects. The students also have family, financial or health challenges that may prevent them from continuing their participation. For example, a student's lack of research experience can lead to underestimating the time required for a project, resulting in missed deadlines and at times, creating real conflicts with students' classes, family commitments, and outside employment. Research projects can have a negative impact on a student's GPA if they are not properly advised and projects are not effectively managed. Finally, community college students do not get any curriculum credit for their undergraduate research as students do for Senior Design Projects at 4-year institutions.

How to Develop an Undergraduate Research Program at a Community College

Since 2010, a wealth of knowledge has been gained on how to start, conduct, maintain, and grow a community college undergraduate research program.

Figure 5 – Process to Develop Undergraduate Research Program at a Community College

This knowledge includes developing a planning team, finding resources, securing faculty participation and administration buy-in, developing relationships/partnerships, and creating a culture that values undergraduate research (Figure 5). One of the first steps is the formation of a team of faculty/staff to plan and manage the program. Team members should have a diverse background to cover a broad range of research topics. They should be committed to addressing the many issues facing a diverse student body. The faculty/staff team should then identify resources (i.e., knowledge, skills, interests, funding, equipment, facilities) necessary for the program and a plan to acquire them. Next, it is essential to obtain the school administration's buy-in. Once this is done, reaching out to companies and other community organizations interested in supporting the research with funding, technical advice, facilities, and ideas for research projects is crucial. Then, resources must be obtained to begin the program along with developing a research application process, which should be clear and easy to follow. Interested students should be provided a research proposal template. It is important to widely advertise the research program with suggested research topics and an opportunity for students to generate their own ideas. Faculty support is key to successful student recruitment, as they are most aware of the skills that would serve a student well in a research project. Recruitment usually occurs through the classroom by professors distributing the information. Also, former research students are asked to give classroom presentations that provide first-hand accounts of their experiences. Interested students and teams should submit formal applications (research proposals) following the established process. The proposal must include a budget, an equipment/supplies list and a project timeline. Workshops should be offered to help students with preparing their proposals. Teams of four are encouraged; however, smaller teams can be accepted if the students demonstrate they have the appropriate discipline, work ethic and accountability to be successful. A faculty/staff selection committee will then evaluate the proposals in terms of quality, research interest, and resources required (e.g., expertise, time, supplies, equipment, funding, faculty advisor). The selection committee is usually comprised of the MESA Center coordinator, grant directors funding the projects and an additional STEM faculty. Once selections are made, teams are notified and required to attend an orientation where students sign agreements, liability waivers and other requisite paperwork. They also interact with other student researchers through team-building activities. Each student also receives a research journal to record their work. Faculty advisors should monitor progress at weekly team meetings. The project should conclude with a

formal written report and poster describing the results of the research including conclusions and recommendations. Student teams should present completed research projects at a formal presentation/symposium at the community college, where students' families, other students, the administration, and public are invited. This event should be used to recruit more students for the program, convince the administration of its viability, provide materials to support future grant applications, and attract new partners from the community. After the first run of a research program, the faculty/staff team should meet to assess the program, recommend adjustments and prepare plans and initiate activities to start the next round of projects.

Conclusion

San Antonio College has been a pioneer in establishing undergraduate research at community colleges. Its success has spawned other community colleges in our district to initiate in-house research programs of their own. The San Antonio College undergraduate research program has grown tremendously since its humble beginnings as a summer-only program to a year-round activity; i.e., from 3 projects and 10 students in 2010 to 8 projects and 38 students in 2018. This experiential learning program has provided substantial benefits to our STEM students to include improved retention, enhanced research, communications, teamwork and leadership skills, and increased opportunities for scholarships, internships and research at 4-year universities.
Future plans are limited only by our imagination. Our primary goal is to increase our numbers in terms of projects, students and involved faculty. We also hope to recruit faculty and students from business, communications, and public relations departments to help manage, document, and publicize ongoing, year-round research projects. The students' success exemplifies what is possible when they apply themselves fully to their studies and the opportunities provided in the undergraduate research program. It is expected that the program at SAC will continue to grow as the school embarks on even more diverse and challenging research. It also means that lab/workshop support facilities will have to expand accordingly. As the program continues to grow, so will training aimed at helping students develop research and critical soft skills. Also critical is obtaining additional grant funding to support our future program. Finally, we plan to increase our outreach and collaborations/partnerships with other schools, commercial firms, and government organizations to increase the help we need with technical expertise, funding, equipment, and materials.

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