

Establishing the Need to Broaden Bioengineering Research Exposure and Research Participation in Mechanical Engineering and Its Positive Impacts on Student Recruitment, Diversification, Retention and Graduation: Findings From the UMBC ME S-STEM Scholarship Program

Liang Zhu¹

Professor
Department of Mechanical Engineering,
University of Maryland Baltimore County,
1000 Hilltop Circle,
Baltimore, MD 21250
e-mail: zliang@umbc.edu

Charles Eggleton

Department of Mechanical Engineering,
University of Maryland Baltimore County,
Baltimore, MD 21250

Ronghui Ma

Department of Mechanical Engineering,
University of Maryland Baltimore County,
Baltimore, MD 21250

L. D. Timmie Topoleski

Department of Mechanical Engineering,
University of Maryland Baltimore County,
Baltimore, MD 21250

Deepa Madan

Department of Mechanical Engineering,
University of Maryland Baltimore County,
Baltimore, MD 21250

The objectives of this study were to evaluate the current status of exposure to bioengineering research in community college (CC) students and University of Maryland Baltimore County (UMBC) students, and to estimate relationships between research activities sponsored by the Mechanical Engineering (ME) S-STEM Scholarship Program and improvement in student enrollment/diversification, retention rates, and graduation rates. The analysis drew on data from ME undergraduate academic records at UMBC from 2008 to 2019. A survey was designed to assess the research exposure of CC and UMBC students and their evaluation of the research components included in recruitment and curriculum activities. Results show that exposure to research measured by attending a research seminar was low for the participants, around 37% for CC students and 21% for ME students at UMBC. The survey results indicate the positive impact of the scholarship programs at UMBC on the research exposure and research experience. The impact is more evident in students who originally transferred from a CC. The large increase in recruited female and CC students over the past 10 years indicated that the research-related activities of the ME S-STEM program played an instrumental role in those increases. Because of the research-related activities, the ME S-STEM program achieved retention and graduation rates higher than those in the ME undergraduate program (89% versus 60% for the 6 year graduation rate), as well a higher percentage of students enrolled in graduate school (30% versus 10%). We conclude that there is still a need to implement research-related activities in the ME undergraduate program, starting with student recruitment and continuing through the academic program. Results suggest that there is a positive impact of ME S-STEM research activities on student diversification, retention rates, and percentage of our graduates who are pursuing graduate degree. [DOI: 10.1115/1.4047839]

Keywords: bioengineering research, incorporation of research in curriculum, diversification, retention, enrollment in graduate school

Introduction

The STEM industries in the United States face a looming retirement cliff as skilled baby boomers begin to retire and leave the workforce. Based on the prediction by Maryland's STEM Report Card [1], the average annual increase in demand for the top 40 STEM jobs has been approximately 6–9%. Moreover, the demand for more highly qualified STEM professionals to fill those positions will continue to grow so that the USA can maintain its

competitive edge. To meet the demands of regional and national employers, it is essential to improve student retention and graduation rates by providing students with a robust and challenging college STEM education.

Traditional university recruitment efforts are focused primarily on high school seniors. Even if community colleges (CCs) are the starting point for many professional engineers, community college students are often underserved by higher education. Demographic data have shown a diverse population in community colleges [2]. Potentially, tapping into the diverse demographics of the community colleges to recruit more students into 4-year STEM degree programs could have a significant impact on the overall diversity in the STEM workforce. This is essential as studies have shown

¹Corresponding author.

Manuscript received April 17, 2020; final manuscript received June 17, 2020; published online September 11, 2020. Assoc. Editor: Alisa Morss Clyne.

that diversity leads to improved decision making, innovation, and good outcomes for businesses [3].

Unfortunately, most community college students need to balance school with financial and family stress. They often enter the workforce directly after their associate degrees. Most community college students have the intention to transfer to a 4-year institution (>80%), but less than 33% actually make the transition [4]. During the academic year of 2008–2009, there were only 17 community college students who transferred to our engineering program, less than 15% of the total student enrollment in our program [5]. With a passive recruitment approach, the major obstacle to transferring was the lack of information on both the transfer process and the responsible contact persons on each campus. Recruitment activities were normally handled by staff in the undergraduate education office. Faculty members with active and ongoing research programs were rarely involved in the recruitment process, and were conspicuously absent in interactions with community college students. Identifying the most effective means to inform local community college students about research and financial opportunities available at 4-year universities is essential to further bolster the transfer process and diversify the STEM student population.

In the Mechanical Engineering (ME) program at University of Maryland Baltimore County (UMBC), only 11.6% of the undergraduate students were women in 2008 [5]. Engineering traditionally has not been the most welcoming profession for women. Workplace sexism, a lack of female role models, and stereotypes stating that women lack an innate technical competency are obstacles that often steer women away from engineering. Mechanical Engineering is the engineering discipline with the highest number of BS degrees awarded annually among all the engineering majors; however, it has the lowest percentage of BS degrees awarded to female students [6]. Compared to biomedical engineering programs, where more than 1/3 of the undergraduate students are female, only 10–13% of the undergraduate enrollments in mechanical engineering were women [7]. Mechanical engineering is a major often perceived to highly mathematical and quantitative. In contrast, disciplines like biomedical engineering are seen as more qualitative and therefore, more accessible. The dramatic difference between the percentages of female students in biomedical engineering and traditional mechanical engineering may be due to the direct impact that biomedical engineering has on people's quality of life and their health. Through interviews with female students in Biomedical Engineering program in various institutions, those female students stated that strong societal impact of their work and the collaborative nature of interdisciplinary research seem appealing to them. It is possible that female students may prefer to have an impact on human health by working with direct medical interventions, rather than traditional ME endeavors that may not require direct contact with other people. At UMBC, although there is no bio-engineering department, a significant number of the mechanical engineering faculty were trained in bio-engineering research and teaching. Showcasing bio-engineering research at the recruitment stage may be a logical and effective approach to attract more female students to diversify the mechanical engineering program at UMBC [8].

Attracting talented students from diverse backgrounds to a 4-year degree program is only a first step. Keeping those students engaged beyond the minimal requirements of the program is the next. Although most universities have existing student support structures and program elements, active mentoring of underrepresented minorities (URMs), female students, and community college students is needed to address the barriers facing them in engineering fields. Those challenges include financial barriers against entering and completing college, a lack of a support network for first generation college students, and inadequate academic preparation for the rigorous engineering programs. Previous research studies suggest that early interventions are effective to prevent students from earning failing grades, mitigate barriers to success, and improve retention [9]. Pro-active faculty mentoring provides a systematic strategy to help students navigate

their educational path and continue to develop coherent approaches toward reaching their goals.

The retention and graduation rates in our engineering program can be improved. For the 2010 cohort of 78 freshman students declaring Mechanical Engineering (excluding transfers), the retention rate was 81% in the first year. But in the second year that number dropped to 74%, and in the third year the retention rate further decreased to 70%. Within mechanical engineering, the 4-year graduation rate was only 23.1% of the students for the 2010 cohort. Even if we include the students who switched from the ME major to other majors to finish college, the 6-year graduation rate was still only around 60%, with ample room for improvement. For the students transferred from local community colleges in the 2010 cohort of 35 students, their retention rates (year 2: 74.3%, year 3: 37%) and 4-year graduation rate (5.7%) trailed those of their peers who started as freshman at UMBC. Studies have demonstrated that integrating a research experience into a student's education program improves retention rates, and plays a role in increasing the percentage of students pursuing graduate degrees. Engaging undergraduate students in research is an effective way to increase students' interest by providing a sense of the profession and broadening students' horizons and perspectives [10–12]. Bio-engineering research has been a strength of the research endeavors in our department. Ongoing bio-engineering research projects in the department include evaluation of microstructural changes in hard and soft tissues with aging and/or diseases, characterization of heat and mass transport in permeable biological tissue in diagnosis and treatment of various diseases, and quantification of nanoparticle transport and its treatment/imaging efficacy in nanomedicine. With our emphasis on bio-engineering research, we were uniquely positioned to address the national need to provide students with career enhancement experiences not normally available to traditional mechanical engineering students. Students with this type of training would have a significant advantage in postgraduate placement, and hence would be actively sought by employers. For example, bio-engineering addresses the national need to serve the aging society by preparing qualified engineers who also understand the societal and economic impacts of aging. Incorporating bio-engineering research-related activities in the undergraduate curriculum may place our students in the center of multiple disciplines, and provide them with enhanced curricula, and research and career experiences, to create a future generation of leaders in bio-engineering to meet national needs.

To address the challenges of recruitment, diversification, retention, and graduation, faculty seek financial support from federal funding agencies to implement research-related activities in the undergraduate curriculum. Starting in 2009, the Mechanical Engineering department at UMBC has been awarded three sequential NSF S-STEM grants to increase student diversity, improve retention, and provide successful paths toward job placement and graduate study in our department. The program builds on efforts to promote interdisciplinary research opportunities that attract underrepresented students to mechanical engineering, improve their retention and graduation rates, and increase their potential for career placement and/or graduate studies. We hypothesize that there is a need to communicate and integrate research activities during student recruitment and during their 4-year academic study, and further, that the research activities have positive impacts on student retention and graduation. This study had two major objectives: first, to evaluate the current status of research exposure in community college students and UMBC students, and second, to estimate relationships between the research activities sponsored by the ME S-STEM program over the past ten years and changes in student enrollment/diversification, retention rates, and graduation rates in both the mechanical engineering program and our scholarship program.

Methods

From 2010 to the end of the 2019–2020 academic year, the ME S-STEM scholarship program provided financial support to low

income students via scholarships, as well as one-to-one faculty mentoring, similar to many other scholarship programs supported by NSF. In addition to scholarship funding and pro-active faculty mentoring, one unique feature of our scholarship program is the incorporation of research into various activities of the program. We exploited the resources of research faculty participating in our S-STEM program to promote and provide research-related activities; such activities are often not accessible to students from low-income families. Those activities included visiting community colleges for recruitment, presenting research seminars to community college students and UMBC students, organizing lab visits for undergraduate students, designing entry-level research seminars, and providing undergraduate students research opportunities. All the faculty members in the S-STEM Scholarship Program conduct biomedical engineering research. Therefore, the research activities of the scholarship program have been focused heavily on biomedical engineering research. In the ME S-STEM program, no studies were done to evaluate whether exposure of traditional mechanical engineering research to our students is equally effective to improve students' retention and graduation rates.

Among those activities, sending research faculty to community colleges and open houses allows them to showcase ongoing research projects in their presentations to promote interest in mechanical engineering. Providing in-depth research lab tours for undergraduate students exposes students to current research projects in the department, and provides them with the opportunity to explore those projects further. Seminars from invited speakers outside of our campus were routinely offered in the department, and were advertised and open to the public; however, there were very few undergraduate students who attended these research seminars. The reluctance to attend may be due to lack of information, conflict of schedules, or perhaps because of the depth of the advanced research topics. Over the past 10 years, we redesigned the seminar series in our department and included entry-level topics on bio-engineering. We have changed the typical practice from inviting speakers only from academics to also inviting speakers from government research labs, researchers in industry, and alumni of our department. The bio-engineering seminar series gave our scholars a broader understanding of potential careers in various aspects of engineering and enabled them to identify potential contacts. Other research-related activities were offering REU opportunities, featuring research results on our website, and covering travel costs for our scholars to attend research conferences. In this study, we measured the needs and impacts of the research-related activities via using surveys given during some of the activities, combined with data on the students' demographics and academic records.

Current Status of Research Exposure in Community College Students and UMBC Students in Our Department. A survey was designed to assess the research exposure of students and their evaluation of the research components included in those activities. The survey was given to community college students during our recruitment presentations, and ME undergraduate students during in-depth lab tours. The surveys were given to all participants after the events and were collected on-site. The surveys for community college students and UMBC ME students were similar. The surveys consisted of 15 questions asking about their demographic background, their previous exposure to research and research experience, and their satisfaction with the event. The IRB at UMBC has approved our research protocol involving human subjects.

During community college presentations by an ME faculty member, the faculty member gave a seminar typically consisting of three parts: (1) a description of the ME S-STEM Scholarship Program at UMBC, (2) the transfer process to the ME program, and (3) ongoing research projects in the faculty's lab at UMBC. For UMBC ME undergraduate students, in-depth lab tours at UMBC were scheduled during a University "free-hour" so that all ME undergraduate students could attend. During the lab visit, the

faculty member gave a Powerpoint presentation, and then a "show and tell" session describing the work, followed by a Q&A session to answer any questions the students may have had.

All survey results were entered into EXCEL for analyses. Not all participants answered every question in the survey. Percentages of participation were calculated based on the sample size of individual groups. Data analyses were conducted to evaluate whether the perceived experiences from exposure to research differed by ethnic group, family educational background, whether the students were community college transfers, and whether the students were part of a scholarship program. The survey results were also used to measure the satisfaction of the participants from the research-related activities, and to collect feedback for future improvements.

Impacts of Research-Related Activities on Students. Students' demographic data within our S-STEM program and the ME undergraduate program were collected via scholarship applications and information compiled by the Office of Undergraduate Education (OUE) at UMBC. Our S-STEM program keeps lists of program activities, attendance of scholars at those activities, their semester retention, final graduation records, and postgraduation placements. The retention rate and graduation rate of regular ME undergraduate students are extracted from a database maintained by the OUE at UMBC. The impacts of the research-related activities sponsored by our program on ME S-STEM students were evaluated by comparing with the general population of ME undergraduate students. Relationships between the research activities and improvement in student diversity and enrollments were assessed by longitudinal demographic data of ME undergraduate students from 2009, when the ME S-STEM Scholarship Program started.

Results and Discussion

Research Exposure and Student Satisfaction of the Research-Related Events. We received 111 surveys after seven community college visits and 79 surveys after two ME lab tours. The top panel of Fig. 1 gives the demographic data of the participants in the surveys. The percentages of any specific group were all higher than 14%, and thus provided good sample sizes for analyses. In both survey groups, more than 30% of the participants were URM defined as African Americans, Hispanics, or Native Americans. There were overlaps between the groups in the demographic data, for example, white and Hispanic, female and white, female and URM. Twenty-six percent of the students in the community college group identified as female, compared to 37% in the UMBC group. Almost 30% of the attendees stated that they were first generation college students. As shown in the bottom panel of Fig. 1, the first generation college students in the community group identified as 66% male and 31% female, compared to 55% male and 41% female in the UMBC group. More than 50% of the first generation college students identified as URM, followed by 30% who identified as white. Students who identified as Asian were the smallest percentage in both groups.

Overall, 27% (community college students) and 32% (UMBC students) of the participants had attended at least one research seminar (Fig. 2). In the community college participants, exposure to research via attending seminars was higher in the URM group (42%) and the Asian group (33%) than the female (21%) or white (19%) groups. In the UMBC ME participants, it was the opposite, with higher percentages of participants in the female and white students. For the first generation college students, their exposure to research was relatively high (34%) for both community college participants and UMBC participants.

Further exposure to research was assessed by students' participation in an REU program. Figure 3 illustrates the marked decrease in the percentages of students having at least one REU experience as compared to those who attended a research seminar.

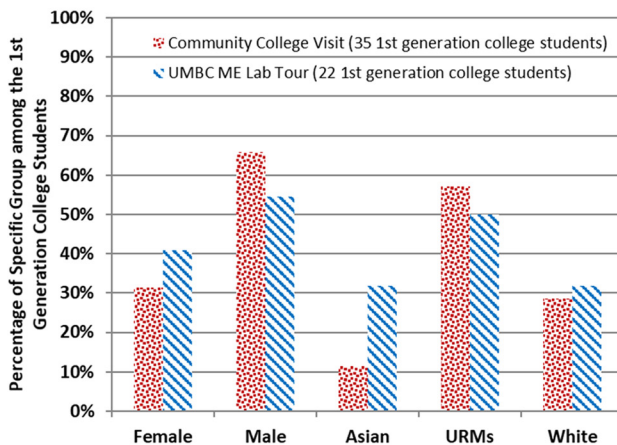
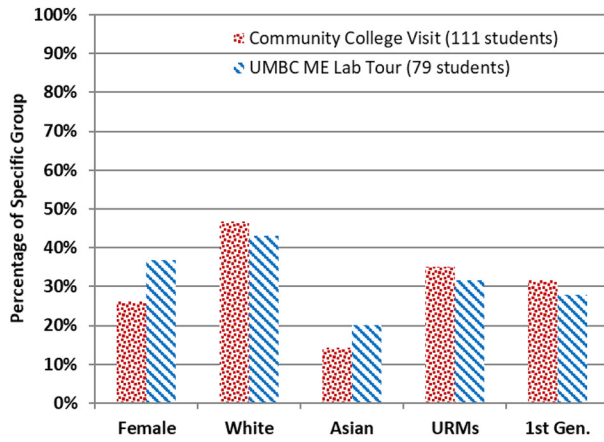


Fig. 1 Percentages of participants' demographic data in the surveys. The top panel shows the data of the entire group, and the bottom panel gives the demographic data of the first generation college students.

Overall, 19% in the community college group and 21% in the UMBC group had at least one experience working in a research laboratory. In the community college students, the URM group had a decreased participation rate in REUs (20%) from that in attending research seminars (42%). The first generation college students showed a notable drop in their participation rate in REUs. In contrast, the white and Asian students had increased participation rates in REUs compared to those who attended research

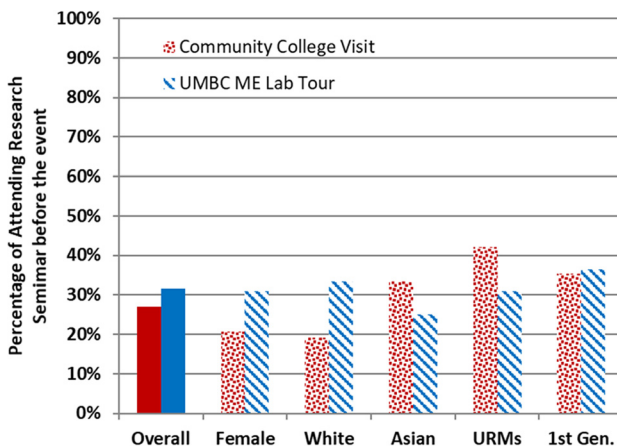


Fig. 2 Percentages of students attending at least one research seminar before the event where the surveys were taken

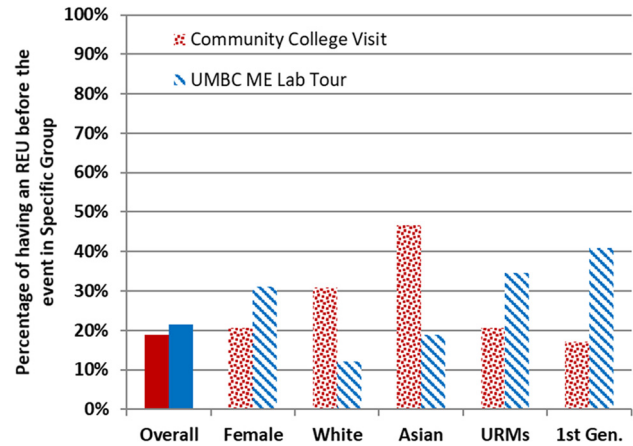


Fig. 3 Percentages of students having at least one REU before the event where the surveys were taken

seminars. For the UMBC students, there were fewer white or Asian students who participated in REUs compared to those who attended research seminars. When comparing the white and Asian students in the two groups, the REU participation rates of the white and Asian students in the community colleges were much higher than those at UMBC. This may be due to the selection bias in the study. During the community college visits, the presentation was typically open to students of an entire class, and their attendance was required by the instructor. However, the lab tours at UMBC might have attracted undergraduate students who did not know the research of the ME faculty and/or did not have REU experience; in another word, the students attended the lab tours because they were curious about research, having little or no previous exposure. Further, at UMBC, URMs, especially African American students, have been encouraged to pursue research due to the nationally renowned Meyerhoff Scholars Program. In comparison, less attention has been given to attracting white or Asian students to research on campus. Additional studies are needed to assess the research experiences of the entire undergraduate population in the department to draw more specific conclusions.

More than 85% of the participants after the community college visits, and 99% of the participants after the lab tours, stated that they understood more of the technical content of ongoing research projects than before they participated in the activities. More than 66% (community college visits) or 87% (UMBC lab tours) were satisfied with the overall event. The higher satisfaction rate in the UMBC group may be slightly biased, since students who attended the lab tours were those who are interested in learning about the ongoing research projects in the ME faculty's lab. There is still room for improvement to boost the satisfaction rate in our community college visits, including contacting the instructor to see which specific topics students may be interested in, and offering seminars focused primarily on research projects. Seventy-two percent of the community college students would like to attend future seminars offered by ME faculty. For the UMBC ME undergraduate students, 85% stated that the experience made them more interested in pursuing undergraduate research, and 96% of them were interested in attending another lab tour in the future.

Impact of Scholarship Programs on Research Exposure.

The survey results were also used to evaluate how the scholarship programs at UMBC promoted research exposure. The ME undergraduate students who participated in the survey identified the ME S-STEM Scholarship Program that our team is managing, the Meyerhoff Scholars Program, and the CWIT Program at UMBC as promoting research exposure. All three scholarship programs provide not only financial assistance, but also engage their scholars in research. The ME S-STEM Scholarship Program also proactively encouraged students who originally transferred from

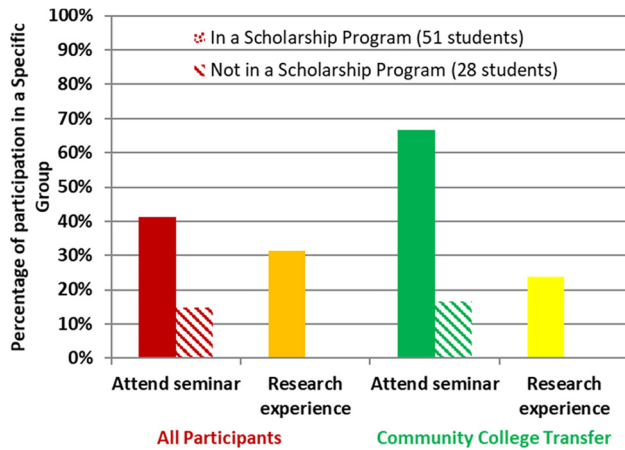


Fig. 4 Different participation rates between students in a scholarship program or students not in any scholarship program in the ME department at UMBC in the survey

community colleges to pursue research. The positive impacts of those scholarship programs on the research participation of students in the ME Department at UMBC are illustrated in Fig. 4. The solid bars represent participation percentage of students who previously attended a research seminar, while the patterned bars represent the percentage of the students who were engaged in research in a lab before the event. For all the students who were part of at least one scholarship program ($n = 51$), 41% of the participants attended at least one seminar, and 31% had at least one research experience in a lab; both percentages exceeded the overall participation percentages of the UMBC students. However, among the 28 participants who were not in any scholarship program, only 15% attended at least one research seminar, and 0% were engaged in a research lab. The results from the 21 UMBC participants who originally transferred from a local community college illustrate similar trends. Among the community college transfer students who are were in at least one scholarship program, 14 (67%) had attended at least one research seminar, and 5 (24%) had an experience working in a lab. However, for the six community college transfer students not in any scholarship program, only one (17%) had attended at least one research seminar, and none of them worked in a research lab.

It was not a surprise to see a low percentage of UMBC students who engaged in a research lab. Most undergraduate students in our department do not appear to know the value of conducting research. They are more interested in getting an internship. Most of them consider getting a job in industry as their primary goal after graduating from our program. They do not see a direct connection between having an REU and getting a job. In addition, summer is usually a time to catch up with missed courses, work to pay for their education expenses, or get an internship in local industry. Our results shows that providing incentives/requirements for students in the scholarship programs boost the percentage of them engaging in REUs, attending seminars, etc. The question is how to expand the practice from the small scale of a scholarship program to the entire undergraduate population. It would require resources at the departmental level and/or college level, as well as departmental and college recognition of faculty involvement in undergraduate education.

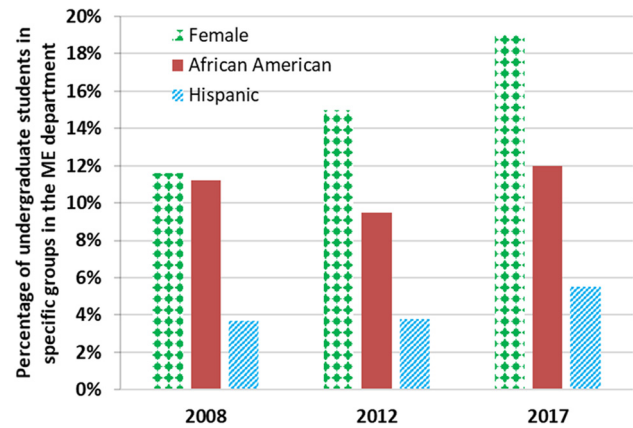


Fig. 5 Percentages of URM groups in the ME undergraduate student population from 2008 to 2017

Improved Student Diversification and Enrollment. Since the ME S-STEM program started in 2009, we have observed a steady increase in the total enrollment in ME department undergraduates. The Mechanical Engineering program at UMBC had 456 full-time (FT) undergraduates in 2009, 527 in 2012, and 579 in 2018, following the national rising trend as compiled by ASEE [6,13]. In addition, the enrollment of community transfer students showed a substantial increase over the past ten years. Approximately, 23% of the undergraduate students in our department transferred from Maryland community colleges in 2009. Table 1 illustrates the distribution of students from five community colleges that transferred to the UMBC ME program. All, except Cecil Community College, have steady increases in the number of students transferring to our department. The last column gives the total number of students that transferred from all 14 of the community colleges in Maryland each year. Compared to academic year 2008–2009, when only 17 students transferred from the community colleges, the ME Department was elated to see that number increased by 170% (46 students) in the 2014–2015 academic year.

Student demographics in our undergraduate program did not reflect those of the Maryland population before 2009. In the 2008–2009 academic year, the enrollment of female full-time students in Mechanical Engineering at UMBC was 11.6%, just below the national average of 11.9% in Mechanical Engineering undergraduate enrollments [13], while the African-American full-time student population was 11.2%, similar to the national average. Of particular note, the percentage of full-time Hispanic students was only 3.7%, and far below both the national average of 6.2% in Mechanical Engineering, and the 6.7% Hispanic population in Maryland; there were no female Hispanic students in our department [6]. As shown in Fig. 5, over the past 10 years the enrollment of female full-time students in our department increased, from 11.6% in 2008, to 15% in 2012, and to 19% in 2017. That number is well above the national average of 11–13%. The number of Hispanic undergraduate students in our department has almost doubled, from 17 in 2008 (3.7%) when our first S-STEM grant started, to 20 in 2012 (3.8%), and to 32 in 2017 (5.5%). The percentage of African-American students varied slightly from 11.2% in 2008, to 9.5% in 2012, and to 12% in 2017 [6]. The fairly consistent percentage of African-American students in our program

Table 1 Numbers of CC students transferred to ME at UMBC per year

Year	Baltimore county	Montgomery county	Anne Arundel county	Cecil county	Howard county	Total from all CCs
F08-S09	4	2	3	0	1	17
F12-S13	10	5	4	2	3	33
F14-S15	15	7	6	0	3	46

Table 2 Retention rate and graduation rate of the ME 2010 and 2012 full time cohort of freshmen

	Retention			Graduation		
	First year	Second year	Third year	Fourth year major	Sixth year major	Sixth year college
2010 cohort	81%	74%	73%	23.1%	55%	60%
2012 cohort	80%	70%	69%	22.7%	32%	64%

may suggest that our approach to attract more African-American students is not effective. More collaboration with the UMBC Meyerhoff Scholars Program is needed to develop more effective recruitment strategies to target African-American students. We can concentrate especially on those students who do not receive a Meyerhoff Scholarship to provide them incentive to enroll at UMBC. Additional outreach to community colleges that serve higher numbers of African-American students may also enable us to increase the student diversity in our department. The S-STEM program offers support using an alternative model to other scholarship programs at UMBC. It is highly likely that the increase in diversity of the undergraduate population in the department was related to the efforts of the S-STEM program to target community college and female students through research components in the recruitment activities.

Impacts on Student Retention and Graduation. Since its founding in 2009, the ME S-STEM program has supported more than 110 undergraduate students from diverse ethnic and economic backgrounds. The performance (as measured by GPA) of economically disadvantaged students is often negatively impacted by their financial difficulties and/or their full-time working status. Taking this into consideration, the minimum GPA requirement to applying for the scholarship was set at a fairly modest 2.75/4.0. It provided a larger pool of applicants, allowing especially more community college students and/or first generation college students to apply. Another requirement for applying for the S-STEM scholarship was financial need. Unlike some other scholarship programs (Meyerhoff Scholars Program and CWIT Program) on campus, that target the top quartile student population, our ME S-STEM scholarship program serves students in the second and third quartiles, specifically to help economically disadvantaged students. The ME S-STEM scholarship program supports students who were not necessarily high performing before joining S-STEM. We postulated that their average GPAs were low, not because they were not capable, but because of other burdens or distractions that affected their study.

Retention and graduation rates for the Fall 2010 cohort in Mechanical Engineering [5] are presented in Table 2. Note that the retention rate refers only to student retention in the ME program. Of the freshman students declaring mechanical engineering as their major, the retention rate was 81% in the first year. In the second year, however, that number dropped to 74%. On average, the retention rate for the first 3 years was 76%. Within mechanical engineering, the 4-year graduation rate was 23.1% for the Fall 2010 cohort of the regular students, and the 6 year graduation rate increased to 50%. When we account for the students who changed their major from ME to another department on campus, the 6 year graduation rate was higher, approximately 60% in the 2010 cohort, suggesting the commitment of those students to finish college. Similar results can be seen in the 2012 cohort of the regular ME students: the 6 year graduation rate in ME was 32%, while their graduation rate from any major at UMBC increased to 64%.

The differences in retention and graduation rates between our scholarship program and the general population of the ME undergraduate program were compared to assess the impact of the scholarship program on ME students. Among the 110 ME undergraduate students supported by the ME S-STEM program since 2009, only 12 of them were not retained by our program, equating to a retention rate of approximately 89%. For the 12 students who left our scholarship program, only two of them dropped out of

college altogether, while the rest either stayed at UMBC or transferred to other university to finish college. Since the ME S-STEM program requires full-time student status, each semester the ME S-STEM scholars enroll in the courses recommended by the ME 4 year curriculum plan. Because of the full-time requirement, the scholars retained in our program will graduate within 4–4.5 years from the ME undergraduate program. If we count only those students retained within our program, a conservative estimate of the 6 year graduation rate within the major is at least 89%, much higher than the percentage for regular ME students. Note that the ME S-STEM scholars have more research exposure than general ME undergraduate students. Those research-related activities may have played an important role in improving retention, especially since the S-STEM students were not necessarily in the top quartile of ME students when they started the program. In fact, a recent survey of our scholars from another study demonstrated that the activities sponsored by our program had positive impacts on their academic retention [14]. Not to our surprise, our scholars cited first the pro-active mentoring from the faculty within our program, followed by internships and most of the research-related activities, as having the most impact on their retention and graduation.

In our department, the percentage of students who enroll in graduate school after their BS degree is typically low (~10%) due to the high demand for engineers by local/national industry. According to ASEE data of students in engineering [6], in 2017 more than 30,000 BS degrees, and almost 10,000 M.S. and Ph.D. degrees, were awarded in Mechanical Engineering in the United States. If one excludes the high percentage (70%) of international students, who received their undergraduate education outside of the USA, in graduate degree programs, a rough estimate shows approximately only 10% of Mechanical Engineering BS graduates pursue graduate M.S. or Ph.D. degrees. In contrast, among the ME-S-STEM scholars who have graduated in the past ten years, 32% went on to pursuing graduate degrees in a STEM major, 64% are now working in a STEM industry, and only 4% are still seeking employment. The percentage of the scholars pursuing graduate degrees in our ME S-STEM program is much higher than that of the general ME student population in the department, and in the nation. The much higher rate of students who pursue graduate degrees indicates the positive impacts our program activities have on our scholars. Regular annual surveys of our scholars have demonstrated that research activities such as lab tours, research seminars, and REU opportunities, as well as community building activities such as lunch with faculty, workshops on graduate school applications, and joining a professional society, contributed positively to their decision to pursue graduate degree [14].

In summary, our study evaluated the current status of research exposure in community college and UMBC students. We found relationships between the research activities sponsored by the ME S-STEM program over the past ten years and improvement in student enrollment/diversification, retention, and graduation rates in the mechanical engineering program in general, and in our scholarship program specifically. The faculty who participated in those activities have predominantly bio-engineering research portfolios. Further, since we do not have a bio-engineering program at UMBC, it is reasonable to assume that the ME students had little previous exposure to biomedical engineering (otherwise, interested students would have enrolled elsewhere). We postulate that exposing mechanical engineering undergraduates to bio-engineering opened new possibilities for the students, and thereby

played a role in the changes and relationships we discovered. Exposure to research, measured by whether the students had attended a research seminar, was low for the participants, around 37% in community college students and 21% in ME students at UMBC. The survey results showed the positive impact of the scholarship programs at UMBC by increasing research exposure and research experiences for our scholars. That impact was more evident in students who originally transferred from a community college. The undergraduate enrollment data in our department since 2009 suggested a 27% increase in enrollment. Data demonstrated a more diversified undergraduate student population, especially in females (from 11.6% to 19% in the ME undergraduate students), and in community college transfer students (increase by 170%). The large increase in recruited female and community college students in the past 10 years indicated that the research-related activities of the ME S-STEM program played an instrumental role in those increases. Compared to the general undergraduate population in ME, the ME S-STEM program has demonstrated much higher retention rate, graduation rate, and percentage of students who pursue a graduate degree. We conclude that there is still a need to implement research-related activities in the ME undergraduate program, starting from student recruitment and in their academic study in our program. Results suggest that there is a positive impact of ME S-STEM research activities on student diversification, high retention rates, and high percentage of our graduates who are pursuing graduate degree.

Funding Data

- NSF S-STEM grant (Grant No. DUE-1742170; Funder ID: 10.13039/100000001).

References

- [1] ASTRA, The Alliance for Science & Technology Research of America, 2019, "Maryland's 2019 STEM Report Card," ASTRA, Online, accessed July 23,

- 2020, https://www.usinnovation.org/state/pdf_cvd/ASTRA-STEM-on-the-Hill-Maryland2019.pdf
- [2] Maryland Association of Community College, 2017, "2017 MACC Databook," MDACC, Annapolis, MD, accessed July 23, 2020, [Mdacc.org/wp-content/uploads/MACC_Databook_FY2017.pdf](https://www.mdacc.org/wp-content/uploads/MACC_Databook_FY2017.pdf)
- [3] Hunt, V., Layton, D., and Prince, S., 2014, "Diversity Matters," McKinsey & Company, New York, accessed July 23, 2020, <https://insurance.ca.gov/diversity/41-USDGDB/GBDEexternal/upload/McKinseyDivmatters-201501.pdf>
- [4] Jenkins, D., and Fink, J., 2016, "Tracking Transfer: New Measures of Institutional and State Effectiveness in Helping Community College Students Attain Bachelor's Degrees," Community College Research Center, Washington, DC, accessed July 23, 2020, <https://files.eric.ed.gov/fulltext/ED563499.pdf>
- [5] Office of Undergraduate Education, University of Maryland Baltimore County, 2017, "Student Data (Private Database Maintained by the Office of Undergraduate Education at UMBC)."
- [6] Yoder, B. L., 2016, "Engineering by the Number," ASEE Profile Reports, ASEE, Washington, DC, accessed July 23, 2020, <https://www.asee.org/papers-and-publications/publications/college-profiles/15EngineeringbytheNumbersPart1.pdf>
- [7] Bowman, K., 2011, "Potential Impacts of Creating Biomedical Engineering Programs on Gender Distribution Within Leading Engineering Colleges," *J. Diversity Higher Educ.*, 4(1), pp. 51–64.
- [8] Tsui, L., 2009, "Recruiting Females Into Male Dominated Programs: Effective Strategies and Approaches," *J. Coll. Admission*, pp. 8–13.
- [9] Olson, S., and Labov, J. B., 2012, *Community Colleges in the Evolving STEM Education Landscape: Summary of a Summit*, The National Academies Press, Washington, DC.
- [10] Hensel, N. H., and Cejda, B. D., 2014, *Tapping the Potential of All: Undergraduate Research at Community Colleges*, Council on Undergraduate Research, Washington, DC.
- [11] Lopatto, D., 2007, "Undergraduate Research Experiences Support Science Career Decisions and Active Learning," *CBE Life Sci. Educ.*, 6(4), pp. 297–306.
- [12] Lopatto, D., 2010, "Undergraduate Research as a High-Impact Student Experience," AACU, Washington, DC, accessed July 23, 2020, <https://www.aacu.org/publications-research/periodicals/undergraduate-research-high-impact-student-experience>
- [13] Gibbons, M. T., 2009, "Engineering by the Number," ASEE Profile Reports, ASEE, Washington, DC, accessed July 23, 2020, <http://www.asee.org/publications/profiles/upload/2008ProfileEng.pdf>
- [14] Zhu, L., Gugunus, J., Eggleton, C., Topoleski, L. D. T., Ma, R., and Madan, D., 2020, "Identifying NSF S-STEM-Sponsored Program Activities That Have a Positive Impact on Mechanical Engineering S-STEM Scholars," ASEE 2020 Annual Conference and Exposition, Montréal, PQ, Canada, June 20–25, Paper No. #29176.