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Establishing the Need toBroaden Bio engineering Research Exposure and Research Participation in Mechanical Engineering and Its Positive Impacts on Student Recruitment, Diversification,Retention and Graduation:Findings From the UMBCME

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ABSTRACT *The objectives of this study wereto evaluate the current statusof exposure to bio-engineering research in community college (CC) students and University of MarylandBaltimoreCounty(UMBC)students,andtoestimaterelationshipsbetweenresearchactivities sponsored by the Mechanical Engineering (ME) S-STEM Scholarship Programand improvement in student enrollment/diversification, retention rates, and graduationrates. The analysis drew on data from ME undergraduate academic records at UMBCfrom 2008 to 2019. A survey was designed to assess the research exposure of CC andUMBC students and their evaluation of the research components included in recruitmentand curriculum activities. Results show that exposure to research measured by attendinga 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 scholar-shipprogramsatUMBContheresearchexposureandresearchexperience.Theimpactis more evident in students who originally transferred from a CC. The large increase inrecruited female and CC students over the past 10 years indicated that the research-relatedactivitiesoftheMES-STEMprogramplayedaninstrumentalroleinthoseincreases. Because of the research-related activities, the ME S-STEM program achievedretentionandgraduationrateshigherthanthoseintheMEundergraduateprogram(89% versus 60% for the 6 year graduation rate), as well a higher percentage of studentsenrolled in graduate school (30% versus 10%). We conclude that there is still a need toimplement research-related activities in the ME undergraduate program, starting withstudent recruitment and continuing through the academic program. Results suggest thatthere 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.*

Keywords*: bioengineering research, incorporation of research in curriculum, diversifica-tion,retention,enrollment ingraduateschool*

Introduction

The STEM industries in the United States face a looming retire-ment cliff as skilled baby boomers begin to retire and leave theworkforce. Based on the prediction by Maryland's STEM ReportCard [1], the average annual increase in demand for the top 40STEM jobs has been approximately 6–9%. Moreover, the demandfor more highly qualified STEM professionals to fill those posi-tionswillcontinuetogrowsothattheUSAcan maintainits competitive edge. To meet the demands of regional and national employers, it is essential to improve student retention and gradua- tion rates by providing students with a robust and challenging col- lege 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 commu- nity 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 that diversity leads to improved decision making, innovation, and good outcomes for businesses [3].

Unfortunately, most community college students need to bal-ance school with financial and family stress. They often enter the workforce

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directly after their associate degrees. Most community college students have the intention to transfer to a 4-year institu- tion (>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 pro- gram [5]. With a passive recruitment approach, the major obstacle to transferring was the lack of information on both the transfer pro- cess and the responsible contact persons on each campus. Recruit- ment 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 col- lege students. Identifying the most effective means to inform local community college students about research and financial opportuni- ties 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 under- graduate students were women in 2008 [5]. Engineering tradition- ally 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. Mechan- ical Engineering is the engineering discipline with the highest num- ber 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 bio- medical engineering has on people's quality of life and their health. Through interviews with female students in Biomedical Engineer- ing 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 underrepre- sented minorities (URMs), female students, and community col- lege 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 net- work for first generation college students, and inadequate aca- demic 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 reten- tion 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 improve- ment. 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 effec- tive 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 micro-structural changes in hard and soft tissues with aging and/or dis-eases, 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 experien- ces not normally available to traditional mechanical engineering stu- dents. 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 engi- neers 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 lead- ers 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 undergradu- ate curriculum. Starting in 2009, the Mechanical Engineering depart- ment 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 interdiscipli- nary 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 stu- dents, 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 pro- gram 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 activ- ities; such activities are often not accessible to students from low- income families. Those activities included visiting community colleges for recruitment, presenting research seminars to commu- nity college students and UMBC students, organizing lab visits for undergraduate students, designing entry-level research semi- nars, and providing undergraduate students research opportunities. All the faculty members in the S-STEM Scholarship Program con- duct 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 effec- tive 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 proj- ects 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 informa- tion, 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 speak- ers 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 con- tacts. Other research-related activities were offering REU opportuni- ties, 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 stu- dents during in-depth lab tours. The surveys were given to all par- ticipants 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 dif- fered 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. Stu- dents' 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 activ- ities sponsored by our program on ME S-STEM students were evaluated by comparing with the general population of ME under- graduate 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.

ResultsandDiscussion

ResearchExposureandStudentSatisfactionoftheResearch-RelatedEvents.We received 111 surveys after sevencommunity college visits and 79 surveys after two ME lab tours.The top panel of Fig.1 gives the demographic data of the partici-pants in the surveys. The percentages of any specific group wereallhigherthan14%,andthusprovidedgoodsamplesizesforanal- yses. In both survey groups, more than 30% of the participantswere URMs defined as African Americans, Hispanics, or NativeAmericans. There were overlaps between the groups in the demo-graphic data, for example, white and Hispanic, female and white,female and URMs. Twenty-six percent of the students in the com-munity collegegroup identified asfemale, compared to 37% inthe UMBC group. Almost 30% of the attendees stated that theywere first

generation college students. As shown in the bottompanel of Fig. 1, the first generation college students in the commu-nity group identified as 66% male and 31% female, compared to55%maleand41%femaleintheUMBCgroup.Morethan50%of the first generation college students identified as URMs, fol-lowed by 30% who identified as white. Students who identified asAsian were thesmallest percentage in bothgroups.

Overall, 27% (community college students) and 32% (UMBCstudents) of the participants had attended at least one researchseminar (Fig. 2). In the community college participants, exposureto 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 whitestudents.Forthefirstgenerationcollegestudents,theirexposur eto research was relatively high (34%) for both community collegeparticipantsandUMBCparticipants.

Further exposure to research was assessed by students' partici-pationinanREUprogram.Figure3illustratesthemarkeddecrease in the percentages of students having at least one REUexperienceas comparedto thosewho attendedaresearchseminar.

Overall, 19% in the community college group and 21% in theUMBC group had at least one experience working in a researchlaboratory.Inthecommunitycollegestudents,theURMgro uphad a decreased participation rate in REUs (20%) from that inattending research seminars (42%). The first generation collegestudentsshowedanotabledropintheirparticipationrateinRE Us.Incontrast,thewhiteandAsianstudentshadincreasedpar-ticipationratesinREUscomparedtothosewhoattendedresearch

seminars.FortheUMBCstudents,therewerefewerwhiteorAsian students who participated in REUs compared to those whoattended research seminars. When comparing the white and Asianstudents in the two groups, the REU participation rates of thewhite and Asian students in the community colleges were muchhigher than those at UMBC. This may be due to the selection biasin the study. During the community college visits, the presentationwas typically open to students of an entire class, and their attend-ance was required by the instructor. However, the lab tours atUMBC might have attracted undergraduate students who did notknow the research of the ME faculty and/or did not have REUexperience; in another word, the students attended the lab toursbecause they were curious about research, having little or no pre-viousexposure.Further,atUMBC,URMs,especiallyAfricanAmeri can students, have been encouraged to pursue research dueto the nationally renowned Meyerhoff Scholars Program. In com-parison, less attention has been given to attracting white or Asianstudents to research on campus. Additional studies are needed toassess the research experiences of the entire undergraduate popu-lation inthe departmentto draw more specificconclusions.

Morethan85%oftheparticipantsafterthecommunitycollege visits, and 99% of the participants after the lab tours, stated thatthey understood more of the technical content of ongoing researchprojects than before they participated in the activities. More than66% (community college visits) or 87% (UMBC lab tours) weresatisfied with the overall event. The higher satisfaction rate in theUMBC group may be slightly biased, since students who attendedthe lab tours were those who are interested in learning about theongoing research projects in the ME faculty's lab. There is stillroom for improvement to boost the satisfaction rate in our com-munity college visits, including contacting the instructor to seewhich specific topics students may be interested in, and offeringseminars focused primarily on research projects. Seventy-two per-cent of the community college students would like to attend futureseminars offered by ME faculty. For the UMBC ME undergradu-atestudents,85%statedthattheexperiencemadethemmoreintereste d in pursuing undergraduate research, and 96% of themwere interested in attendinganotherlab tour inthe future.

ImpactofScholarshipPrograms on Research Exposure.The survey results were also used to evaluate how the scholarshipprograms at UMBC promoted research exposure. The ME under-graduate students who participated in the survey identified the MES-STEMScholarshipProgramthatourteamismanaging,theMeyerhoff Scholars Program, and the CWIT Program atUMBCas promoting research exposure. All three scholarship programsprovide not only financial assistance, but also engage their schol-ars in research. The ME S-STEM Scholarship Program also pro-activelyencouragedstudentswhooriginallytransferredfrom \community colleges to pursue research. The positive impacts ofthose scholarship programs on the research participation of stu-dentsintheMEDepartmentatUMBCareillustratedinFig.4.The solid bars represent participation percentage of students whopreviously attended a research seminar, while the patterned barsrepresent the percentage of the students who were engaged inresearch in a lab before the event. For all the students who werepart of at least one scholarship program (*n*51), 41% of the par-ticipants attended at least one seminar, and 31% had at least oneresearch experience in a lab; both percentages exceeded the over-allparticipation percentages ofthe UMBC students. However,among the 28 participants who were not in any scholarship pro-gram, only 15% attended at least one research seminar, and 0%wereengaged in a research lab. The results from the 21 UMBCparticipants who originally transferred from a local communitycollege illustrate similar trends. Among the community collegetransfer 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 commu-nity college transfer students not in any scholarship program, onlyone (17%) had attended at least one research seminar, and none ofthem workedin a research lab.

Itwasnotasurprisetoseealowpercentageof UMBCstudents who engaged in a research lab.Most undergraduate students inour department do not appear to know the value of conductingresearch.Theyaremoreinterestedingettinganinternship. Mostof them consider getting a job in industry as their primary goalafter graduating from our program. They do not see a direct con-nection between having an REU and getting a job. In addition,summer is usually a time to catch up with missed courses, work topay for their education expenses, or get an internship in localindustry. Our results shows that providing incentives/requirementsfor students in the scholarship programs boost the percentage ofthem engaging in REUs, attending seminars, etc. The question ishow to expand the practice from the small scale of a scholarshipprogram to the entire undergraduate population. It would requireresources at the departmental level and/or college level, as well asdepartmental and college recognition of faculty involvement inundergraduateeducation.

ImprovedStudentDiversificationandEnrollment.Since theME S-STEM program started in 2009, we have observed a steadyincrease 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, fol-lowing the national rising trend as compiled by ASEE [6,13]. Inaddition, the enrollment of community transfer students showed asubstantial increase over the past ten years. Approximately, 23%of the undergraduate students in our department transferred fromMaryland community colleges in 2009. Table 1 illustrates the dis-tributionofstudentsfromfivecommunitycollegesthattransferredto

the UMBC ME program. All, except Cecil Community College, have steady increases in the number of students transferringto our department. The last column gives the total number of stu-dents that transferred from all 14 of the community colleges inMarylandeachyear.Comparedtoacademicyear2008–2009,when only 17 students transferred from the community colleges,the ME Department was elated to see that number increased by170%(46students)in the2014–2015academic year.

Student demographics in our undergraduate program did notreflectthoseoftheMarylandpopulationbefore2009.Inthe2008–2009 academic year, the enrollment of female full-time stu-dents in Mechanical Engineering at UMBC was 11.6%, just belowthe national average of 11.9% in Mechanical Engineering under-graduate enrollments [13], while the African-American full-timestudent population was 11.2%, similar to the national average. Ofparticular note, the percentage of full-time Hispanic students wasonly 3.7%, and far below both the national average of 6.2% inMechanicalEngineering,andthe6.7%HispanicpopulationinMaryland; there were no female Hispanic students in our depart-ment[6].As shownin Fig.5,over thepast10yearsthe enrollmentof female full-time students in our department increased, from11.6% in 2008, to 15% in 2012, and to 19% in 2017. That numberis well above the national average of 11–13%. The number of His-panicundergraduatestudentsinourdepartmenthasalmostdoubled, from 17 in 2008 (3.7%) when our first S-STEM grantstarted, to 20 in 2012 (3.8%), and to 32 in 2017 (5.5%). The per-centage of African-American students varied slightly from 11.2%in 2008, to 9.5% in 2012, and to 12% in 2017 [6]. The fairly con-sistentpercentageofAfrican-Americanstudentsinourprogram maysuggestthatourapproachtoattractmoreAfrican-Americanstu-dentsisnoteffective.MorecollaborationwiththeUMBCMeyerhoffScholars Program is needed to develop more effective recruitmentstrategies to target African-American students. We can concentrateespeciallyonthosestudentswhodonotreceiveaMeyerhoff Scholar-ship to provide them incentive to enroll at UMBC. Additional out-reachtocommunitycollegesthatservehighernumbersofAfrican-Americanstudentsmayalsoenableustoincreasethestudentdiver-sity in our department. The S-STEM program offers support usingan alternative model to other scholarship programs at UMBC. It ishighlylikelythattheincreaseindiversityoftheundergraduatepopu-lation in the department was related to the efforts of the S-STEMprogram to target community college and female students throughresearchcomponentsintherecruitmentactivities.

ImpactsonStudentRetentionandGraduation.Sinceitsfounding in 2009, the ME S-STEM program has supported morethan110undergraduate studentsfromdiverseethnicandeco-nomic backgrounds. The performance (as measured by GPA) ofeconomically disadvantaged students is often negatively impactedby their financial difficulties and/or their full-time working status.Taking this into consideration, the minimum GPA requirement toapplying for the scholarship was set at a fairly modest 2.75/4.0. Itprovided a larger pool of applicants, allowing especially morecommunity college students and/or first generation college stu-dents to apply. Another requirement for applying for the S-STEMscholarship wasfinancialneed. Unlikesome otherscholarshipprograms (Meyerhoff Scholars Program and CWIT Program) oncampus, that target the top quartile student population, our ME S-STEMscholarshipprogramservesstudentsinthesecondandthird quartiles, specifically to help economically disadvantagedstudents. The ME S-STEM scholarship program supports studentswhowerenotnecessarilyhighperformingbeforejoiningS-STEM.Wepostulatedthattheir average GPAswerelow, notbecause they were not capable, but because of other burdens ordistractions thataffectedtheirstudy.

RetentionandgraduationratesfortheFall2010cohortinMechanical Engineering[5]arepresentedinTable2.Notethatthe retention rate refers only to student retention in the ME pro-gram. Of the freshman students declaring mechanical engineeringas their major, the retention rate was 81% in the first year. In thesecond year, however, that number dropped to 74%. On average,the retention rate for the first 3 years was 76%. Within mechanicalengineering, the 4-year graduation rate was 23.1% for the Fall2010 cohort of the regular students, and the 6 year graduation rateincreased to 50%. When we account for the students who changedtheir major from ME to another department on campus, the 6 yeargraduationratewashigher,approximately60%inthe2010cohort, suggesting the commitment of those students to finish col-lege. Similar results can be seen in the 2012 cohort of the regularME students: the 6 year graduation rate in ME was 32%, whiletheirgraduationrate fromany majorat UMBCincreasedto 64%.

The differences in retention and graduation rates between ourscholarshipprogramandthegeneralpopulationoftheMEunder-graduateprogramwerecomparedtoassesstheimpactofthescholarship program on ME students. Among the 110 ME under-graduate students supported by the ME S-STEM program since2009, only 12 of them were not retained by our program, equatingto a retention rate of approximately 89%. For the 12 students wholeftourscholarshipprogram,onlytwoofthemdroppedoutof college altogether, while the rest either stayed at UMBC or trans-ferred to other university to finish college. Since the ME S-STEMprogram requires full-time student status, each semester the MES-STEMscholarsenrollinthecoursesrecommendedbytheME4 year curriculum plan. Because of the full-time requirement, thescholars retained in our program will graduate within 4–4.5 yearsfrom the ME undergraduate program. If we count only those stu-dentsretainedwithinourprogram,aconservativeestimateofthe6 yeargraduation rate within the major is at least 89%, muchhigher than the percentage for regular ME students. Note that theME S-STEM scholars have more research exposure than generalME undergraduate students. Those research-related activities mayhave played an important role in improving retention, especiallysince the S-STEM students were not necessarily in the top quartileof ME students when they started the program. In fact, a recentsurvey of our scholars from another study demonstrated that theactivities sponsored by our program had positive impacts on theiracademicretention[14].Nottooursurprise,ourscholarscitedfirstthepro-activementoringfromthefacultywithinourprogram,followed by internships and most of the research-related activities,as havingthemostimpact on their retention andgraduation.

Inourdepartment,thepercentageofstudentswhoenrollin graduate school after their BS degree is typically low (10%) duetothehighdemandforengineersbylocal/nationalindustry.According to ASEE data of students in engineering [6], in 2017more than 30,000 BS degrees, and almost 10,000 M.S. and Ph.D.degrees, were awarded in Mechanical Engineering in the UnitedStates. If one excludes the high percentage (70%) of internationalstudents, who received their undergraduate education outside ofthe USA, in graduate degree programs, a rough estimate showsapproximately only 10% of Mechanical Engineering BS graduatespursue graduate M.S. or Ph.D. degrees. In contrast, among theME-STEMscholarswho havegraduated inthe pasttenyears,32% went on to pursuing graduate degrees in a STEM major, 64%are now working in a

STEM industry, and only 4% are still seek-ing employment. The percentage of the scholars pursuing gradu-ate degrees in our ME S-STEM program is much higher than thatofthegeneralMEstudentpopulationinthedepartment,andinthe nation. The much higher rate of students who pursue graduatedegrees indicates the positive impacts our program activities haveon our scholars. Regular annual surveys of our scholars have dem-onstrated that research activities such as lab tours, research semi-nars,andREUopportunities,aswellascommunitybuildingactivities suchaslunchwithfaculty,workshopsongraduateschool applications, and joining a professional society, contrib-uted positivelyto theirdecision topursuegraduate degree [14].

Insummary,ourstudyevaluatedthecurrentstatusofresearch exposure in community college and UMBC students. We foundrelationships between the research activities sponsored by the MES-STEM program over the past ten years and improvement in stu-dent enrollment/diversification, retention, and graduation rates inthe mechanical engineering program in general, and in our schol-arship program specifically. The faculty who participated in thoseactivities have predominantly bio-engineering research portfolios.Further,sincewedonothaveabio-engineeringprogramatUMBC, it is reasonable to assume that the ME students had littlepreviousexposuretobiomedicalengineering(otherwise,inter-ested students would have enrolled elsewhere). We postulate thatexposingmechanicalengineeringundergraduatestobio-engineeringopenednewpossibilitiesforthestudents,andthereby playedaroleinthechangesandrelationshipswediscovered.Exposure toresearch,measuredbywhetherthestudentshadattended a research seminar, was low for the participants, around37% in community college students and 21% in ME students atUMBC. Thesurvey results showedthe positiveimpact ofthescholarship programs at UMBC by increasing research exposureand research experiences for our scholars. That impact was moreevident in students who originally transferred from a communitycollege.Theundergraduateenrollmentdatainourdepart mentsince 2009 suggested a 27% increase in enrollment. Data demon-strated a more diversified undergraduate student population, espe-cially in females (from 11.6% to 19% in the ME undergraduatestudents), and in community college transfer students (increaseby170%). The large increase in recruited female and communitycollege students in the past 10 years indicated that the research-related activities of the ME S-STEM program played an instru-mental role in those increases. Compared to the general under-graduatepopulationinME,theMES-STEMprogramhasdemonstrated much higher retention rate, graduation rate, and per-centage of students who pursue a graduate degree. We concludethat there is still a need to implement research-related activities inthe ME undergraduate program, starting from student recruitmentand in their academic study in our program. Results suggest thatthere is a positive impact of ME S-STEM research activities onstudent diversification,high retention rates,andhigh percentageof ourgraduates whoare pursuinggraduate degree.

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