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Women and BIPOC in Aerospace: Where Did They Come From and How Did They Get Here?

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Abstract

The low number of women and black, indigenous, and people of color (BIPOC) compared to their population, is well-documented in engineering, engineering technology, and other STEM fields. Through this and ancillary documentation there is agreement that increasing the numbers of women and other minorities in these areas will enhance productivity and the breadth of new innovation. Many efforts have been made to increase the number of women and BIPOC in STEM fields. The result of those efforts has been disappointing as they have resulted in minimal growth in engineering and virtual stagnation in other areas of STEM.

The aviation and aerospace industries are facing significant difficulties in filling technical positions for people with STEM credentials. One may argue that current conditions create a slowdown in the demand for people in these positions; however, the current slowdown in aerospace provides time to further develop the pipeline to be ready for the expected resurgence of need in this area. To meet this demand, targeted efforts need to be designed and implemented to attract, educate, employ, and retain these highly skilled women and the BIPOC demographic. Since these groups are historically underrepresented in STEM, an added opportunity to bridge the population gap in fields such as those identified in the aerospace industry. This study aims to review the existing research on why women and BIPOC enter technical fields, the challenges they find, what makes them stay or leave, and what are some of the alternative pathways to increase the population of women and BIPOC in the aerospace industry.

Keywords: Aviation, Aerospace, Diversity, BIPOC, Workforce, Women, Female, Black, Indigenous, Persistence, Retention

Introduction

The world is changing. According to the US Census Bureau the percentage of the population that is white and non-Hispanic will reduce by over 9% between 2016 and 2060 [7]. This increase in non-white populations is not represented in the science, technology, engineering, and mathematics (STEM) workforce. Hispanics are 15% of the US population, but they account for only 6% of STEM workforce [8]. Blacks represent 12% of the population but are only 5% of the STEM workforce [8]. For women, the difference is even more egregious. Women are 51% of the population but are only 15% of the engineering workforce [8]. There is opportunity to increase participation in STEM fields for women and black, indigenous, people of color (BIPOC).

Deloitte and Datawheel [1] report the gender composition of the aviation mechanics and technician industrial workforce is 35% women. Additionally, half of the college-educated workforce is women, yet only 28% of the science and engineering are filled by women [2]. Racial demographics indicate that these numbers mirror women representation throughout the population. White, non-Hispanic mechanics and service technicians comprise 65% of this population while White, Hispanic mechanics represent 11%. Overall, the remaining workforce consists of 24% for BIPOC [1].

In a time where there are difficulties reaching other populations such as engineering technology programs, the aviation industry is facing a significant shortfall of technicians and technologists. Boeing [3] provides estimates of nearly $2.4 B in maintenance and engineering over the next 20 years; this translates into nearly 800,000 new and existing positions in these areas. Currently, while there is an increase in the number of certified airframe and powerplant technicians this year, there needs to be an increase of 37% to meet the projected demand [4].

The need for increased diversity, especially in the aerospace industry, is needed because the industry is becoming more global with increasing collaboration between countries and companies. This increased cooperation means requires greater diversity is needed to ensure policies, procedures, tools, and methods meet the needs of everyone involved. Diversity is also good for companies. Diversity in the workforce results in greater organizational effectiveness, increased morale, and greater productivity [9]. Diversity is also a stated goal of many aerospace companies.

Literature Review

To increase diversity of women and BIPOC in the aerospace engineering and engineering technology fields, the existing research must be understood. What are the established pathways and challenges for entrance into the aerospace workforce? What lessons can be learned from other STEM fields for recruitment and retention? This study aims to review the existing research on why women and BIPOC enter technical fields, especially aerospace, the challenges they find, why they stay or leave, and what are some of the alternative pathways to increase the population of women and BIPOC in the aerospace industry.

Demand for Technicians. The demand for technicians and technologists in the aerospace industry in total is not available through the US Bureau of Labor Statistics (USBLS) website (www.bls.gov). The US demand for aircraft and avionics mechanics and technicians is expected to grow 5%, with an increase in employment of 7,300 from 2019-2029 which does not include the replacements due to retirement or other attrition [10]. The outlook for Aerospace Engineering and Operations Technicians is expected to grow 7%, with an increase of 800 technicians between 2019-2029 [11]. The outlook for Aerospace Engineers is listed as an increase of 1900 between 2019-2029 [12]. These are only a fraction of the technically demanding careers for degreed technologists and technicians in the aerospace industry which typically includes fixed wing and rotary wing aircraft, unmanned aircraft, spacecraft, satellites, and missiles. Therefore, the demand predicted by the two major global commercial aircraft companies is presented to provide indications of demand in commercial aircraft, military aircraft, and space aircraft.

Airbus [13] predicts the global number of aircraft to double by 2039, traffic to double by 2035, and $4.9 trillion in aircraft services through 2039. Aircraft services demand in North America will need over 76,000 new technicians in North America [13]. The Boeing [14] *Pilot and Technician Outlook 2020-2039* forecasts 739,000 technicians are needed worldwide, with 192,000 of those needed in North America; this forecast includes the effects of the COVID-19 pandemic. Innovations such as increased use of technology, immersive virtual and hybrid delivery, and competency-based assessments are changing technician education from prescriptive to more holistic; these changes and exemptions driven by COVID-19 may be

evaluated to become the norm [14]. Even with the effects of COVID-19 decreasing passenger traffic and increasing freight traffic, the demand for commercial aircraft is expected to grow 3.2% and traffic to grow 4.0%, with a demand for over 2 million personnel worldwide [15]. The demand for commercial aviation services is expected to be $1.925 Billion in North America; $9 trillion worldwide [15]; these services typically require highly trained technicians and technologists to plan and conduct heavy maintenance and modifications, freighter conversions and digital equipment modifications. The production of UAS aircraft is expected to increase substantially by 2030 [16]. Deloitte [17] expects defense to grow at 2.8%, space launch services to grow 15% or higher year over year, and space exploration and space investments to grow in 2021 globally. While this is not a complete estimate of forecasted demand, it does show that demand is strong in the aerospace industry.

Women and BIPOC in Aerospace. Early in developing higher learning institutions, most programs that required an interest in technical fields limited enrollment to men [18]. Women were not considered "worthy" of this kind of study as they would become homemakers and not need this kind of education [19]. Society supported those stereotypes; thus, it took some time to move out of that and allow, not only women, but anyone other than the traditional white, male student body into those classrooms, some fields more so than others [20]. While there is improvement, it is not the case in many parts of the United States and other parts of the world, as the stigma of women entering these fields still exists [21].

The challenge to attracting women to STEM fields was set some time ago. The dilemma is how to change the stereotypes and self-image of women students to the various areas where these pre-established concepts stunt enrollment, matriculation, and graduation. Evidence produced by researchers connects that the lack of role models and the impact it has on these students; supporting their concept that if someone that "looks like them" did it, they can too [22].

When students see someone doing a job, they assume that they can do it too [23], [24]. If they do not see those that look like them, the notion that they could do a particular career or task is not conceivable to them. Similar issues confronted medicine; frequently, one hears stories of women practicing medicine on the frontier. This was not a regular occurrence until the early 1980s, and now the demographic profile nearly matches the profile of a generalized population. The changes to the medical profession's demographic are primarily attributed to the perceptions of younger students. Much of that can be ascribed several reasons including marketing materials that provided images of women and under-represented minorities working as medical doctors. Their doctors were increasingly women in family practice. Funding of medical doctors was geared toward the altruistic side of practicing medicine. These are all things used by that field to attract younger students as they consider possible careers.

One of the more specific concerns in STEM is the majors with smaller numbers of students relative to engineering and the sciences. A focus on women students choosing aviation as their life's vocation has been the subject of interest to many researchers [25]. Fewer women [26] are pursuing degrees in aviation and other high-tech STEM fields, except for life sciences. Some believe the solution to this dilemma is filling the pipeline at the university or college level, leaving suggestions to achieve this task to outreach and nonspecific partnership/relationships as the means to achieve this task [26]. Recent work by Ferla and Graham [27] suggests that the

identification and understanding of the barriers is the solution to changing the demographics in the aviation industry and then provide strategies for recruitment and retention of these students and future professionals.

Strategies identified include the increase in women as role models, which is also supported by research focused on other areas [27]; [28], [29], [30]. Others suggest that offering women as mentors is critical to support other women, and those programs should be run by women [31], [32], [33]. Other suggestions were to increase education regarding the field without introducing bias or reinforcement of gender roles, providing financial assistance programs directed to the desired population, and being proactive when dealing with discriminatory behavior [27].

While women searching for a career path are often swayed by the popular misnomer of these being fields that are part of a "white man's game" [33, p 137]. This is a result of discrimination toward both women and minorities [33] and the continuation of male dominated culture [33]. While these similarities exist in these areas, further study reveals that the aviation industry has several unique issues that are the result of exclusion of women from the military [33]. Many pilots and other aviation careers began in the military [33], while others may be attributed to an aviation event, and others involved in aviation [34], [35]. This is where aviation careers differ between other STEM fields. There are clear career paths and areas that provide experience that supports continued education and a pursuit of aviation careers. Whereas the delineation of the same for other STEM fields is not always as clear.

Impact of Diverse Workforce. Studies have shown that innovation and market growth are spurred by having a diverse workforce, with companies who embrace alternative approaches to developing talent and diversifying their staff become more competitive [36]. Despite the interest in creating a diverse workforce, companies struggle to find the talent necessary to fill open positions. This expanding problem of human capital development is more than the inability to fill positions; it adversely impacts a company's ability to grow and expand their market share, resulting in a stifling of economic growth [37].

When deciding what human capitol strategy to adopt, companies must weigh various operational costs around hiring external versus internal upskilling and training programs. The company must decide what is the best pathway to low cost, high quality talent acquisition [37]. Many generations ago much of the world embraced the use of apprenticeships to train and retain individuals across a wide spectrum of work roles, including STEM occupations; the U.S. did not adopt this approach. Instead, apprenticeships were used to fill skilled trade positions (i.e., construction, plumbing, culinary, etc.). With the increased focus on apprenticeships in the U.S., other apprenticeship occupations have emerged, such as those in transportation, nursing aids, childcare, auto and diesel mechanics, and technicians for manufacturing. It is noteworthy that within the last several years apprenticeship programs in Information Technology (IT) and cybersecurity have exploded on the scene. This expansion in occupations has effectively put the U.S. in-step with the world in offering apprenticeship beyond the skilled trades. Whether new to the apprenticeship arena or not, all these occupational fields share the same common issue; the ever-growing gap between the number of open positions versus the number of skilled people, especially women and BIPOC, to fill them.

Workforce Recruitment. Companies have relied upon traditional methods of finding talent, hiring from universities, "poach" from other companies, or the use of staffing agencies and consultants to fill critical shortages. Despite these efforts, companies continue to lag in plugging the ever-expanding talent gap. Because of the increased difficulty in finding talent, companies are starting to explore the use of apprenticeships as a "new" way to fill the gap. Despite this renewed interest and promotion of apprenticeships, women and BIPOC are grossly underrepresented in STEM-focused occupational training programs. At secondary and post-secondary levels, women make up less than 20% in architecture and construction, manufacturing, transportation, distribution, and logistics fields [38]. Perkins IV reports data for enrollment in Career and Technical (CTE) programs at the secondary level. Enrollment by gender is reported in Figure 1. Enrollment by race is reported in Figure 2. Data for these tables were collected from the Perkins web portal. Annual reports do not report on enrollment by race in CTE year over year, so it is unclear why the increase in enrollment after 2009-10. The consistency of the numbers before and after indicate there may have been a change in how data were collected.

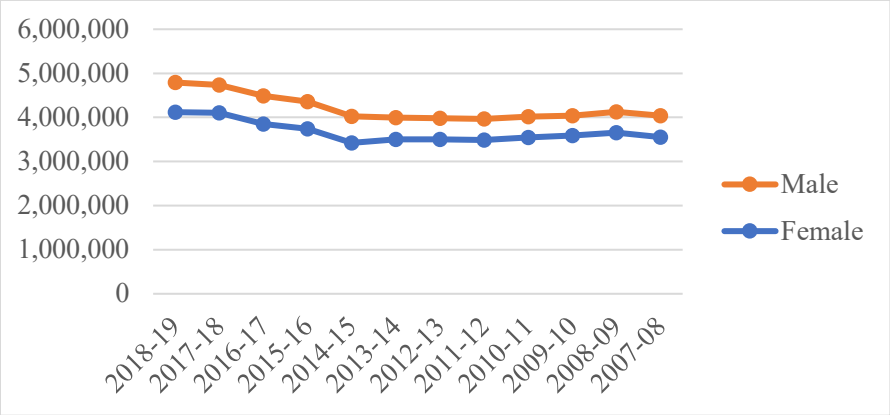

Figure 1 Enrollment by gender in CTE programs at the secondary level [39].

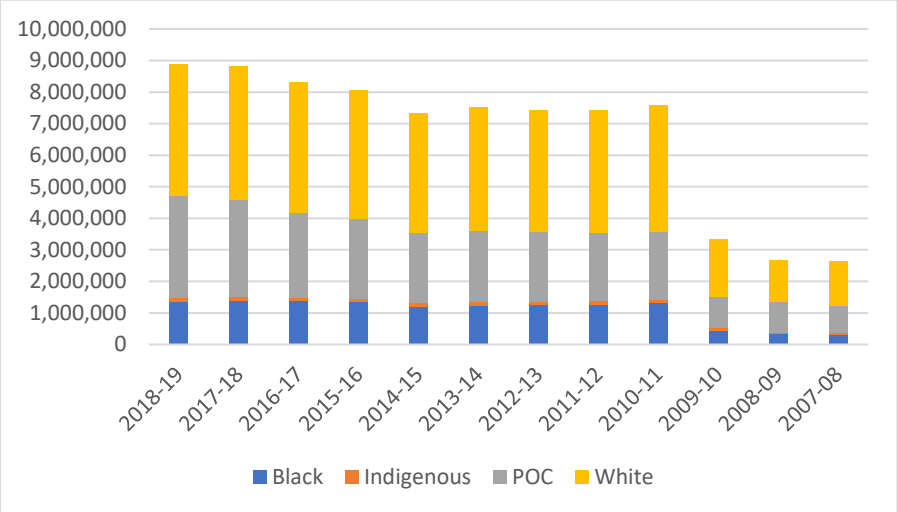

Figure 2. Enrollment by race in CTE programs at the secondary level [39].

Apprenticeships. Apprenticeships are industry-driven programs created so employers grow their own talent through the combined use of paid, on-the-job-learning, and job-related classroom instruction to acquire skills and nationally recognized credentials [40]. The value of apprenticeships was illustrated by a U.S. Department of Labor funded study that found 97% of the employers would recommend an apprenticeship to other employers, with 86% saying they would strongly recommend adopting apprenticeship programs in their workplace [41]. Additionally, over 80% of the employers reported that apprenticeships were invaluable to filling critical openings, with 72% using the program as a mechanism to vet the quality of worker before the permanently hiring them. Furthermore, 68% of employers said having an apprenticeship raised their productivity while strengthening worker morale and pride. In fact, 63% said that they did not find the cost of training to be a barrier or cause a significant financial burden. The overwhelming majority of the employers shared they saw a significant increase in recruitment, retention, and successfully obtaining critical licensing requirements because of their respective apprenticeship programs [41]. Studies have shown that apprenticeships provide return on investment (ROI) for companies, regardless of the type of apprenticeship. A study conducted in Europe found that companies with engineering apprenticeships were net-neutral with respect to programmatic cost in two of the programs and achieved a positive ROI by year three of a four-year apprenticeship [42]. Together, these benefits point to a workforce strategy that companies facing critical talent shortages should consider implementing.

The U.S. Department of Labor Women's Bureau analyzed multiple apprenticeship programs to identify the best practices and strategies that employers might implement as part of an apprentice program. Businesses that utilized these strategies saw significant increases in the recruitment and retention of women and BIPOC hired by their company. Although historically most women tend to participate in apprenticeships in the social services (i.e., childcare, culinary, nursing aids, etc.), there is an effort to recruit more women to participate in STEM apprenticeship programs. Adoption of these best practices as part of a STEM or aerospace apprenticeship are recommended to build a stronger pipeline. The best practices focus on supportive services, ranging from developing mentorship opportunities; engaging with peers; and showcasing and connecting them to role models within the company. Other strategies include company-based case managers that provide recurring coaching, encouragement to help build self-confidence, and communication with the apprentices, along with financial assistance to remove barriers that often prevent a person from entering or successfully completing the training program [40].

Retaining women in engineering.

There is a large pool of literature on the experiences that women face in engineering careers. A limitation in the literature, however, is the lack of literature in engineering technology or the aerospace industry in particular. The use of the research on the experiences of women in engineering can be informative of the experiences of women and BIPOC in the aerospace industry.

While the number of bachelor's degrees in engineering and computer science awarded to women increased 40% between 2012 and 2017, women make up only 13% of the workforce in engineering, and only 30% are still in the workforce 20 years later [43]. The numbers of women and BIPOC in general are low universities, there is evidence that retention is higher for women

and BIPOC. Graduation rates for the closest analog to aerospace engineering, mechanical engineer, find that for those who graduate with a degree in engineering, who started in engineering, are highest for Asian females at approximately 60% and white males are approximately 56% [44]. Black males have the lowest graduate rate at slightly above 40%. The reasons for the turnover are still being researched to identify the reasons and what can be done to increase retention, but there are some prevailing theories.

The male dominated culture creates an environment that women, and most likely BIPOC, find difficult. Women find their male colleges are more likely to socialize more with each other both at work and after hours [45]. This imbalance creates opportunity for closer relationships between the men that could translate into greater opportunities for promotion or the feeling of exclusion for the women. This feeling of exclusion can also be exacerbated by the use of gendered language [45]. The default language is to identify engineers as men. Women as engineers are invisible in conversation.

What makes them stay? Women report that they are more likely to stay in their career if they are able to identify as an engineer [46]. Meaning they attribute common characteristics of engineers to themselves such as being a problem solver or analytic thinking. Confidence, or self-efficacy, is also a factor [46], [47]. Workplace supports, such as training and development, are found to be a predictor for persistence [47]. Interestingly, persistent engineers framed their career in a why that connected it to others. They used terms such as collaboration, support, counsel, and consequences [46]. Non-persistent, former, engineers were more self-focused. They talked about how things impacted them or sought recognition from others.

Discussion/Conclusion

There is clearly a disconnect between the need for employees in the aerospace industry and the number of candidates available for filling that need. Research shows that under representation is a significant contributor to the low percentages of women and BIPOC in the aerospace industry. If women, especially young women, do not see other women in jobs in aviation, they may not consider aviation as a viable career option. According to Women in Aviation [48], only 2.5% of aviation mechanics are women. When women make up half the population, this is a tragically low number. The numbers for BIPOC aviation mechanics are unknown since neither the FAA nor BLS collect these data [49]. The numbers of BIPOC are not expected to be high.

There are many reasons for these low numbers, but one of the most commonly accepted is the low amounts of visibility of women or minorities currently in aerospace positions. This finding is common for both women and BIPOC, and this includes industry employees and faculty at education institutions. It is not uncommon for an aviation maintenance school or training program to include only one, or no, women or minority faculty members.

In addition to more visibility, there needs to be additional pathways to industry. According to the FAA, by far the most common way (62%) aircraft mechanics received certification was through an FAA-approved aviation maintenance technical school [49]. Only 28% achieved certification through an alternate path that included practical work experience. The Department of Labor (DOL) is a source of grant funding to support apprenticeship programs for both women and

BIPOC populations [49]. Other pathways into the aerospace industry, such as apprenticeships, can reach new populations that are not being well-served by the traditional four-year college experience.

Conclusion

The lack of diversity, both gender and racial, in the aerospace industry is not new, nor has it been ignored. Unfortunately, efforts have so far have not been as successful as the aerospace industry would like it to be. This is a problem that has been seen and solved in other industries, such as healthcare. It will take significant effort, but there is reason for hope. Visibility has been shown to help young girls and minorities feel as if there is a place for them. Apprenticeships can provide a way for students who are not able to attend or succeed in a traditional four-year program to begin a career in the aerospace industry. Future research may provide additional insight into the challenges faced by women and BIPOC in aerospace.

Future work

Future work in this area should focus on three major areas for increasing the numbers of women and BIPOC in the aerospace industry: 1) increasing the visibility of women and BIPOC in these careers, 2) developing and promoting alternate pathways to these careers; and 3) understanding why women and BIPOC enter and leave the aerospace industry. One of the first actions may be to survey women and BIPOC to understand their experiences specifically in the aerospace industry, and not engineers or technologists in general. So far there does not seem to be a significant difference in the overall reasons why there are few women and BIPOC professionals in aerospace, but more targeted research may identify differences. If so, then those differences should be explored.

Through the use of established DOL and FAA grants, alternate pathways, such as apprenticeship, may be established. There are many examples of existing programs that can be benchmarked when creating new programs. For example, AAR Corp., an aviation services company specializing in aircraft maintenance, repair, and overhaul, established the EAGLE Career Pathway program in Indianapolis [50]. This is a program that connects students who want to pursue their airframe and powerplant certificate (A&P) to a school and future jobs in the aviation industry. Students receive up to $15,000 in tuition assistance from Vincennes University in exchange for working at AAR Corp. [50]. This is just one possible pathway. There are other frameworks that can be used to identify and support younger students to pursue a career in the aerospace industry.

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