

Increasing Investment in STEM Education for Females: Policy Considerations

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Abstract

During this difficult economic time, as policy makers decide how to use their limited resources to help prepare the rising generation for the demands of an ever-changing workforce, aligning K-12 educational priorities with higher education and economic development can help maximize public dollar investments in STEM education, particularly when females are given access to STEM and STEM-related education and programs. Smart public policy initiatives can help increase the representation of women in technology, research and development, and innovation departments.

The purpose of this article is to provide policy recommendations that could help increase gender diversity and participation in STEM education pipelines and stimulate innovation. Viewing public dollar investments in female STEM education as an economic development tool not only encourages diverse participation in traditionally male dominated industries but can help leverage STEM education into an economic driver that promotes strong technology sectors in state economies.

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Literature Review

Women in Science

Gender disparities in patenting are well documented in the sciences. Women overall do not patent nearly as much as men. Women are listed as inventors on around 10% of all U.S. origin patents and hold approximately the same share of patents in Europe (Hunt et al., 2012; Sugimoto et al., 2015). Of those patents, even fewer are commercialized. Hunt et al., observe that underrepresentation of women in patent-intensive fields is a key determinant of the patenting gap (2012).

The mechanisms of discrimination that cause gaps in the number of patents granted need to be addressed in order to recruit and retain women into male-dominated fields (Hunt, 2010). Additionally, a focus on mentoring and improving professional networks will benefit women and create a more inclusive environment within the sciences. Though women patent less in quantity, the quality of their work warrants an investment (Whittington and Smith-Doerr, 2005). Providing institutional support for the commercialization of intellectual property created by women is necessary to combat these disparities.

Universities are a place to focus efforts to address gender disparities in patenting. Women are more likely to develop patents in a university setting than in the private sector (Sugimoto et al., 2015). Universities have begun to expand the criteria for academic productivity by including things like patenting and other commercial innovation. As these approaches become more accepted in university culture, women will be incentivized to pursue patenting, whereas it is currently viewed as optional (Sugimoto et al., 2015). Other support structures, such as the presence of a university technology transfer office, foster increased participation from women in patenting (Guiri et al., 2020). Commercialization of research is not without its critics, enabling women to bring beneficial innovations to the market rather than merely seeking patents should be the aim (Melo-Martin, 2013).

Diversity and Innovation

Diversity drives innovation and productivity. The composition of a firm affects the quality of ideas and the likelihood of innovation. Gender diversity throughout a firm, not solely jobs requiring creativity, is positively associated with more innovation (Ostergaard et al., 2011; Huo, Motohashi and Gong, 2019) and with more radical innovation (Diaz-Garcia, Gonzalez-Moreno and Saez-Martinez, 2013). Firms with more diversity were more likely to report growth in market share from year to year (Hewlett, Marshal and Sherbin, 2013). The benefits of gender diversity have been widely researched, but simply adding women into a firm does not produce innovation. Support structures need to be in place to create an environment that is inclusive of women, where diversity is normative (Turban, Wu and Zhang, 2019; Post et al., 2009).

Gender Occupational Segregation

Gender occupational segregation research within corporate structures reveals a lack of representation of women in executive leadership positions (Baldwin & Ackerson, 2017), while very few studies have focused on the gender composition within innovation departments.

As women make progress towards equity in the labor market, occupational segregation within companies and labor sectors is a defining feature and accounts for much of the gender wage gap (Cortes and Pan, 2017). Though the wage gap has narrowed in recent decades, and women are entering fields traditionally dominated by men, disparities remain (Blau and Kahn, 2000, 2006, 2017). Traditional explanations for wage gap differences, such as disparities in human capital measured through educational attainment and full-time work experience have less salience. Human capital has been shown to have a diminished role in explaining the wage gap as the differences in full-time experience between men and women has steadily declined over the last few decades. Women have also exceeded men in the attainment of advanced degrees (Blau and Kahn, 2017).

Occupational segregation remains an important variable for calculating wage differences between men and women. If women and men with equal credentials and experience levels are separated by type of employment, then the wage is determined within each occupation and the true disparity is masked. If women in traditionally male occupations come closer to parity with men's wages, then it is important to note that a woman's career pathway and consideration for employment opportunities is different than her male counterparts within a labor sector or within a company. Much of the research looking into gender occupational segregation focuses on women's representation in managerial and executive positions. Research consistently shows overall that women are excluded from these high earning, high prestige positions even when they are well represented within an industry more generally (Repetti and Hoffman, 2018).

In addition to occupational segregation, explanations for the wage gap have included outright discrimination, differences in human capital, and the division of labor within families. Discrimination persists and has been widely documented (Correll, Benard and Paik, 2007; Reuben, Sapienza and Zigales, 2014; Williams and Ceci, 2015; Moss-Racusin et al., 2012). Gender roles and division of labor within the home also affect women's participation in the labor market, including the number of hours they can work and types of jobs they accept. Women who are unable to work longer hours earn less in wages (Blau and Kahn, 2017).

The gaming industry follows suit with other corporate hierarchies, wherein women are highly represented in middle management roles but are disproportionately represented in upper management (Repetti and Hoffman, 2018). The strides women have made within corporate hierarchical structures by attaining employment in upper management and executive level positions across industries is important but focusing exclusively on upper management and C-Suite representation neglects supervisory and other management positions where women are underrepresented and where resources can be focused to improve gender equity, such as creating a pipeline for female talent.

Given the pattern of gender disparity in patenting in STEM and STEM-related fields and the growing evidence of the benefits of diverse innovation teams, we assess how these patterns are reflected in the technology, research and development, and innovation departments of gaming manufacturers in the gaming industry and consider how they can be addressed.

Creating a More Diverse Workforce Through Investments in STEM Education

The gaming industry is the largest industry in Nevada. If progress is to continue in the effort to create a more diverse workforce in Nevada, it will be necessary to ensure that limited resources are used judiciously. As policymakers consider where investments in education can have the biggest impact in economic development, creating pathways from K-12 to higher education to workforce development can result in substantial returns on public dollar investments. There are several pathways that, if structured properly, will be mutually reinforcing and allow for scarce resources to be effectively leveraged for a maximum return on investment. Smart public policy initiatives can help increase the representation of women in technology, research and development, and innovation departments not only in gaming but across a variety of industries.

As we considered ways to measure the contributions of women to technology, research and development, and innovation departments, we took into account patent holders working in STEM and STEM-related industries to see how patent holders in Nevada gaming compared to the rest of United States. Because the gaming industry is the largest in Nevada and gaming manufacturing companies provide employment in a wide-variety of STEM and STEM-related fields such as computer science, computer engineering, software development, and mathematics, we felt an examination of the intellectual property created by gaming manufacturing companies would provide a good snapshot of how women compare to men in the technology, research and development and innovation segments of one of Nevada's most important industries.

We found a total of 292 U.S. utility and design patents from 2017-2019 issued to four major gaming manufacturing companies with headquarters in Nevada. We verified the gender of the inventors using publicly available data on company websites and social media sites. From that data, we found that each of the gaming manufacturing companies had an overwhelming majority of male inventors (95.4%) and a very small proportion of women (4.6%). At 4.6%, the number of patents issued to women at gaming manufacturing companies was less than half of the US national average for women listed on patents, which was about 12%, during the same period ¹ (US Patent and Trademark Office, 2020). We also discovered that in Nevada's gaming manufacturing sector at least one female inventor is included in only 6.8% of all issued patents, again well below the U.S. national average of 21.9% (US Patent and Trademark Office, 2020).²

Of the top 29 U.S. patent-assignees, the majority are technology companies. Interestingly, the same gender disparities that exist in the gaming manufacturing sector of the gaming industry were found to exist among the majority of those companies as well (US Patent and Trademark Office, 2020). It is interesting to note that among females applying for patent, there is a higher concentration of women pursuing employment in chemistry, biology, and related STEM, as opposed to electrical and mechanical engineering (US Patent and Trademark Office, 2020). While the data points to a significant under-representation of women in the creation and development process, it does not provide insight into the factors that limit women's participation in innovation.

Finding ways to include women and broaden diversity is critical. If women are not well represented in engineering and computing, innovation suffers. Engineering and technology companies will have smaller talent pools from which to draw upon and become less globally competitive (Corbett and Hill, 2015). As Nevada policymakers work to leverage scarce resources to promote gender inclusion, diversity, and participation in STEM and STEM-related fields and work to improve economic diversity, we offer the following recommendations:

Federal and State Resources – Making Smart Investments

Investments made in STEM education for females from pre-kindergarten through 12th grade will generate significant long-term dividends. As more women become interested in and seek STEM-related employment, their economic circumstances improve as does their overall sense of well-being. The American Association of University Women reports that women in engineering and computing make more than 90 cents for every dollar a man makes for comparable full-time work, experience a high degree of job satisfaction, enjoy greater workplace flexibility and attain more independence than other professional women do (Corbett and Hill, 2015).

While STEM education can be funded in various ways, this article focuses on state budgetary grant funding. Grant funding is a flexible yet accountable method of providing funds to promote and cultivate programming for specific needs. The 2019 Nevada Legislature provided \$4.0 million in STEM grants for the 2019-2021 biennium with \$2.0 million expended each year (Nevada Legislative Counsel Bureau, 2019). The funds were distributed via 5 different grants established through the STEM Challenge Grant Program (Nevada Legislative Counsel Bureau, 2019).

STEM Workforce Challenge Grant

The STEM Workforce Challenge Grant is a

[c]ompetitive grant program to create or expand STEM postsecondary workforce training programs for Associates Degree programs. This grant also pro-

¹The number of patents issued to female inventors in the United States grew from 12.1% in 2016 and 12.8% in 2019.

²When looking at contributions to patents in the gaming manufacturing sector in Nevada by gender, women account for 4.6% of first-listed inventors, 10% of second-listed inventors, and 9.5% of third-listed inventors.

vides startup funds for programs that meet the following criteria: Identification of STEM-specific skills needed by employers in Nevada; creation of programs that provide education and skills-training to workers that match the needs of employers; programs that are aligned with the present and future workforce needs identified through labor market information (LMI); and programs that are sustainable after grant funds have been exhausted. (Nevada Legislative Counsel Bureau, 2019, p. 4)

Funding for this grant was \$1,375,000 for each year of the biennium (Nevada Legislative Counsel Bureau, 2019).

STEM Workforce Pathway Grant

This competitive grant program provides “high school students in public schools in Nevada with the opportunity to earn or progress toward an industry-recognized, high demand, STEM postsecondary credential, certificate, or degree” (Nevada Legislative Counsel Bureau, 2019, p. 4). The grant also supported “high school instructors with the professional development and certifications necessary to teach high demand STEM programs” (Nevada Legislative Counsel Bureau, 2019, p. 4). Funding for this grant was \$300,000 for each year of the biennium (Nevada Legislative Counsel Bureau, 2019). With 500,860 students enrolled in Nevada’s public education system for the 2019-2020 school year the grant fund amounts to around \$1.00 per student if approximately \$100,000 was used for teacher professional development.

Increased investment in this grant program to recruit and include more students along with alignment between the Clark County School District and Nevada System of Higher Education could begin to develop a pathway from K-12 to higher education, result in greater efficiencies and yield higher returns on the state funding investment.

STEM Workforce Marketing Grant

This grant “[p]rovides startup funds for outreach and marketing of new and expanded STEM training programs and efforts that would lead to increased enrollment and address the STEM workforce shortage in industries such as health care, advanced manufacturing, and IT” (Nevada Legislative Counsel Bureau, 2019, p. 4). Funding for this grant is \$50,000 for each year of the biennium (Nevada Legislative Counsel Bureau, 2019). The gaming manufacturing segment should work toward creating STEM training programs for their technology needs. Alignment between Nevada System of Higher Education and workforce development to ensure continuity could result in increased awareness of existing STEM training programs. Public dollar investment should also be increased in this grant program. A 2019 expenditure of \$50,000 spread across multiple industries for marketing and outreach for a total workforce of 1,527,359–1,550,143 people seems as if it might be a needle in a haystack in terms of market penetration (Nevada, Department of Education, Training and Rehabilitation, 2021).

STEM Leaders Academy Grant

The STEM Leaders Academy Grant “[p]rovides a workforce training program for STEM teachers and school administrators to increase the quality of STEM education throughout the state by providing consultation, professional development and strategic planning assistance to leaders from aspiring STEM schools” (Nevada Legislative Counsel Bureau, 2019, p. 5). Funding for this grant is \$250,000 for each year of the biennium (Nevada Legislative Counsel Bureau, 2019).

Engineering Fellows Grant

This grant creates an opportunity to develop mentorships by incentivizing

licensed educators teaching 5th grade to partner with local professional engineers and engineering students from the University of Nevada, Las Vegas and the University of Nevada, Reno to develop and integrate the Next Generation Science Standard (NGSS)-aligned engineering design with existing curriculum. (Nevada Legislative Counsel Bureau, 2019, p. 5)

Funding for this grant is \$25,000 for each year of the biennium (Nevada Legislative Counsel Bureau, 2019). This is a great example of how aligning K-12 education with higher education in creative and productive ways to educate students can leverage scant resources to wisely use them.

An examination into the levels at which our neighbor state, California provides grant funding for STEM education magnifies just how inadequate grant funding for STEM is in Nevada. In 2013, California created its competitive grant process, the California Career Pathways Trust and provided \$750 million in funding over 3 years (Education Commission of the States, 2016). At \$4 million, Nevada has funded its STEM grant funding at a level of less than 1% of California's level.

According to the State of Nevada, Department of Education, during the 2019-2020 school year there were 500,860 students enrolled in its public education system which equates to an approximate investment of \$3.99 per student in total STEM grant funding (State of Nevada Department of Education, n.d.). The figures aren't much better for the 2020-2021 school year which saw a student enrollment of 486,633 and an investment of about \$4.10 per student. Using data reports from the California Department of Education's website, the State of California had student enrollments of 6,236,672 for the 2013-2014 school year, 6,235,520 for the 2014-2015 school year and 6,226,737 for the 2015-2016 school year (California Department of Education, n.d.). At \$250 million per year in grant funding, California provided grant funding at a rate of roughly \$40.00 per student each funding year. California's investment in STEM education has been able to attract and retain technology companies such as Oracle, Apple, Facebook, VMware, Symantec, Google and Adobe.

Another way in which Nevada could incent women to obtain STEM education and innovate would be to establish grant funding for the commercialization of intellectual property through the Nevada System of Higher Education. The work done by Sugimoto et al., 2015 and Guiri et al., 2020 lends support to this type of public investment and suggests that women would be more likely to contribute as innovators in a university environment.

Encouraging Diversity in STEM Education Begins in Childhood

While grant funding for STEM is critical, it is not the only conduit available to encourage girls and young women. Developing the following tools or educational programs could help stimulate interest for young women in STEM and STEM-related fields:

- Identifying girls with an affinity for STEM-related subjects early in their education. Fewer women are graduating with university degrees in STEM compared to men, despite overperforming in academic achievements and overall degree completion (Card and Payne, 2021; Conger and Long, 2010). Focusing on younger girls early in their science careers can address these gaps. Research on middle-school aged girls shows that their desires to participate in STEM do not always align with how they view their own science-identities and career paths, particularly for girls of color (Tan et al., 2013). Girls need to be identified and supported so they can see themselves as scientists.
- Providing additional educational supports for girls and young women. Many models for improving STEM performance among girls have shown that investment in

this effort returns good results. For example, educational summer camps for middle school girls with hands-on activities have been shown to increase interest among participants in STEM-related careers (Levine et al., 2015). It is important to note that for young girls to see themselves in a career, they must see others like them in such positions. Representation of women in the field as role models is key to recruiting young women into traditionally male dominated fields (Milgram, 2011). Developing mentorship programs that pair girls with women working in STEM fields would provide tremendous support to adolescent girls as they navigate their paths. Educational content that is gender-specific and culturally relevant will also increase girls' participation (Young et al., 2017). Additionally, educational support such as computer coding classes and tutoring can address any skills gaps that girls have.

- Aligning K-12 educational priorities and spending with the Nevada System of Higher Education, coupled with the appropriate course curricula and workforce development can lead to an increase in better paying technology jobs for women.

It is anticipated that STEM jobs will grow 17% over the next two decades, at a faster rate than non-STEM jobs (Education Commission of the States, 2015). Despite the increase in STEM-related jobs, women are not seeing any meaningful improvement in STEM employment. Indeed, “[w]omen remain as scarce as ever in engineering, computing, and advanced manufacturing” (Education Commission of the States, 2015, p. 2). Out of the 84% percent of high school students that graduate, only 25.6% go on to obtain a certificate or degree in a STEM field (Education Commission of the States, 2019).

Despite a lack of longitudinal research specific to the various STEM disciplines, investment in early childhood STEM initiatives can result in significant dividends:

Several studies have shown that children's mathematics achievement at kindergarten entry predicts later math and literacy achievement even more than early literacy ability does. Further, high-quality STEM experiences provide young children with opportunities to develop critical thinking, executive functioning, and problem-solving skills that cut across subject areas (within and outside of STEM disciplines) and that set the stage for how they approach learning and thinking about rich content into the future. (Early Childhood STEM Working Group, 2017, p. 6)

Alignment of Nevada System of Higher Education and Workforce Initiatives

Education Initiatives are another way to include women in STEM-related education and industries. Finding innovative ways to be inclusive and introduce STEM education to students who may be intimidated or inexperienced can increase student access to STEM education. As Livingston (2020) discovered:

One leader who understands the difference is Maria Klawe, the president of Harvey Mudd College. She concluded that the only way to increase the representation of women in computer science was to treat men and women differently. Men and women tended to have different levels of computing experience prior to entering college—different levels of experience, not intelligence or potential. Society treats boys and girls differently throughout secondary school—encouraging STEM subjects for boys but liberal arts subjects for girls, creating gaps in experience. To compensate for this gap created by bias in society, the college designed two introductory computer-science tracks—one for students with no computing experience and one for students with some computing experience in high school. The no-experience course tended to be 50% women whereas the some-experience course was predominantly men. By the end of the semester, the students in both courses were on par with one another. Through this and other equity-based interventions, Klawe and her team

were able to dramatically increase the representation of women and minority computer-science majors and graduates. (p. 7.)

Working with academic institutions to find increased access to STEM curriculum as part of the STEM pathway alignment is an efficient way to leverage limited public funding. Finding ways to partner with industry stakeholders to create internships, apprenticeship programs, and pathways to employment can increase the likelihood that women will be successful in securing STEM and STEM-related jobs.

As girls and young women are encouraged to pursue STEM educational pursuits, they will begin to see themselves as capable of finding employment in technology sectors, the benefits of which are enormous. Technology jobs an underexplored area by women, tend to pay more, have reasonable working hours, and come with valuable employee benefits (Corbett and Hill, 2015). As women begin to see themselves as capable of obtaining employment in the manufacturing and technology sector of the gaming industry, diversity will increase, innovation can be spurred, and new product lines can be pursued.

Educational Opportunities

As illustrated by the data gathered for this article, the gender disparities represented by filed patent applications in the manufacturing and technology segments of the gaming industry are considerable. While much of the focus on diversity has been aimed at the C-Suite, a more representative workforce in technology, research and development, and innovation has largely been ignored. In order to foster innovation, a more balanced workforce with increased diversity is needed.

In 2013, the University of Nevada, Las Vegas through the Center for Gaming Innovation (CGI) launched an ambitious program designed to teach game design and innovation in the gaming industry. The gaming innovation class is open to students from all majors and to non-registered students. The objective of the program is not just to teach game design, but to provide students with an experiential learning experience through mentorship with experienced and successful innovators.

CGI invests in the strongest student innovations and helps develop them into viable commercial products. This includes filing patents, developing prototypes, and finding appropriate industry partners for sale, licensing, development, and/or investment. The CGI has filed over 30 patent applications with 18 patents issued to date. Of those 18 patents, 6 (33.3%) include a woman as a listed inventor, and in all 6 a woman is the first-named inventor. In addition to these patents, the total commercialization value of intellectual property developed by women (both patented and non-patented) participating in the program exceeds \$150,000. The CGI has also been successful at promoting the creative talents of students of color, with 9 of 18 issued patents (50%) including a student of color among listed inventors.

The CGI's record for encouraging, supporting, and developing the intellectual property of women significantly outperforms the gaming manufacturing industry. The CGI's patented ideas include new concepts that successfully merge casual social game elements with casino game design as well as patents for enhanced security designs to prevent cheating at card games. Women constitute a sizable portion of casino patrons and revenue (see Figure 1). Yet, the data shows that women are significantly underrepresented in the creation of new games and technology for the industry. The underrepresentation of women and their ideas in this space limits the industry's ability to develop innovations that appeal to the broad interests of players generally and women in particular.

The reasons for women's diminished representation in intellectual property development in the gaming industry is complex and likely reflects a combination of factors, including a need to better promote STEM education to women. The CGI's model, with an emphasis on applied development of innovations, shows that a new and inclusive approach to fostering innovation for women and students of color can play a significant role in cultivating diversity in gaming innovation.

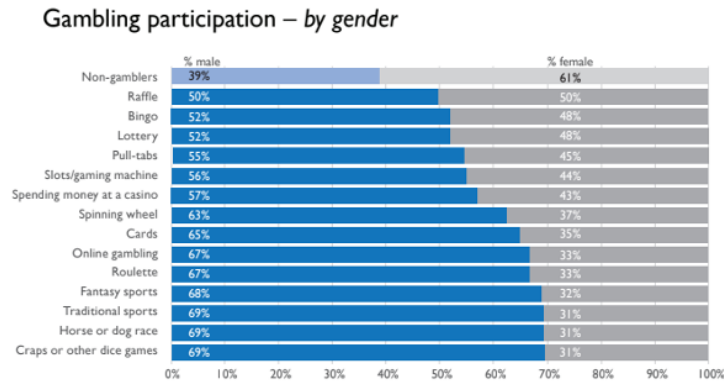


Figure 1
Gambling Participation by Gender (National Council on Problem Gambling, 2021)

Employment Recruiters

Recruiters and head-hunters for technology jobs are not casting a wide enough net. Part of the challenge for women is that employees are often recruited into research and development departments in-house. Women do not always have the ability to self-select into those employment opportunities. If women began designing technology products for women, the benefits would be tremendous. There would be an innovation revolution (women creating products from their perspective) with an abundance of new ideas, that would lead to better technology products. As the technology, research and development, and innovation departments of gaming manufacturers and gaming technology companies become more diverse, there will be better representation of traditionally marginalized employee populations and an increase in profitability.

Conclusion

Gender disparities are common in STEM and STEM-related fields. Nowhere is it more apparent than in patenting. Investing in STEM education is a critical path for improving female representation. These investments should begin during early childhood education to support girls in their pursuits of STEM and STEM-related education. At the college and university level, much can be done to encourage women’s participation and nurture the kind of skill development that will lead to success in technology, research and development, and innovation. Partnerships between universities and industry stakeholders also provide pathways for women. Women who might not see themselves as inventors can explore these careers in a low-risk setting. The small number of women currently participating in gaming innovation underscores the untapped potential for expansion in this field. Expanding women’s participation in gaming innovation will provide many opportunities for women and improve the quality of innovations that will have commercial appeal. Developing policies that will put more women in these roles will only benefit companies and the women they hire.

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