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Early Exposure to STEM and Self-Efficacy: Determinant Drivers to a Successful Engineering Career

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ABSTRACT: There is a global consensus that a shortage in the percentage of women who pursue college majors or careers in science, technology, engineering, and mathematics (STEM) persists. Scientists, economists, and industry leaders believe lower percentages of women participating in STEM fields can deteriorate the ability for the U.S. to compete globally. To increase the representation of women in STEM fields, K-12 math and science teachers, career advisors, and college recruiters are critical. The focus of this research examines the findings of a study that explored professional challenges faced and strategies employed by female engineer executives. At the time of the study, a descriptive qualitative methodology using a phenomenological lens was used. Purposive sampling with criteria for inclusion, exclusion, and maximum variation was applied. Eleven female executives between the ages of 44 to 66 who held a minimum bachelor's degree in engineering (one executive was a geologist), built careers in the oil and gas industry, and held a position of vice-president or higher were interviewed. Strict protocols were used in sample selections, the development of interview questions, and coding of the data.

KEYWORDS: Engineer, STEM, 21st-century learning, self-efficacy, oil & gas corporation

Introduction

In the world of work, technological and economic changes over the past few centuries represent three major industrial revolutions: (a) machine-driven production during the late 18th century; (b) mass manufacturing production in the late 19th century; and (c) desk top computers and the advent of the Internet following the 1950s (Frey & Osborne 2013). Notwithstanding, America has entered the fourth industrial revolution represented by hyper-automation, artificial intelligence (AI), big data, and the Internet of things (IoT), which has increased industrial management and production (Park 2018). Moreover, the accelerating of digitalization will have an enormous impact on career experiences and development for those in the workforce.

Considered to be the most critical economic and technological trends globally, automation and digitalization will fundamentally change how groups conduct business in contemporary society (Arntz, Gregory, & Zierahn 2016; Brynjolfsson & McAfee 2014; Ford 2015; Frey & Osborne 2013). Surprisingly, scholars, researchers, and HR professionals have been silent regarding these challenges (Arntz, Gregory, & Zierahn 2016; Brynjolfsson & McAfee 2014; Ford 2015; Frey & Osborne 2013). For example, these changes will likely result in the loss of thousands of jobs and negatively impact marginalized groups who historically have shown low numbers in technical STEM-related fields (Park 2018). Moreover, a sizable impact on many of these disruptions on the inadequacy of employees is far-reaching (Cribb & Glover 2018). In the shadows of these challenges, U.S. leaders are entrusted to mitigate the scarcity of women in science, technology, engineering, and mathematics (STEM) fields and create pathways for executive-level positions in which they can assume (Hanson & Johnston 2014). In this study, a review of the plight of females in STEM fields is provided. This research highlights findings from an early study around strategies female engineer executives applied during their career trajectories. The empirical study was a descriptive qualitative methodology using a phenomenological lens. Specifically, the research was an exploration of factors that inspired women to pursue an engineering career and strategies they employed as engineer practitioners that led to an executive-level position (Houston 2019). The identified strategies were instrumental in the development of high-performing teams in which innovative and creative methods of problem-solving resulted in high profits and sustainability.

To exemplify the findings of the strategies female engineers employed that led to successful careers in STEM fields, this study is structured into four sections. The study provides a primer of implications regarding the underrepresentation of women in STEM fields. Unsurprisingly, the field of engineering represents an acute case as a highly male-dominated profession, thereby increasing the potential for the phenomena of interest to be observed (National Science Foundation, 2015). Specifically, this study contributes to the literature by exploring the following areas: (a) the status of girls and women in STEM and Bandura's Self-efficacy Theory, (b) 21st-century STEM learning experiences, (c) statistics and the underperformance of American children, (d) engineering education for the next generation, (e) strategies employed by female engineer executives that led to successful careers in engineering, and (f) the methodology and data from the earlier study followed by highlights of the findings, recommendations, and conclusion.

Relevant Literature

Status of Girls and Women in STEM

Female participation in STEM-centric education and employment remains low, and the attrition rate is particularly high (Spearman & Watt 2013). Moreover, women leave STEM disciplines disproportionately while in college and shortly after entering a STEM profession. Additionally, large gender gaps have been observed in science, with girls opting out more than boys (Spearman & Watt 2013). Furthermore, PISA 2015 found in OECD countries, higher levels of science achievement were associated with higher expectations to work in science-related fields. For example, more than 40% of the top-performing girls have career expectations in science as compared to 16% among the lowest performers.

Moreover, UNESCO's STEM and Gender Advancement (SAGA) project has found the gender gap in science increases significantly during the transition from acquiring a bachelor's degree to post-graduate levels (Hausman & Johnston 2014). In the U.S., there is a dire need for creative engineering solutions to solve complex problems in a global economy (Hausman & Johnston 2014). Yet, women are markedly underrepresented in STEM fields not only in the U.S. but, in many countries (Mozahem et al. 2019). Interestingly, globally the number of female college graduates outnumber their male graduate counterparts (Mozahem et al. 2019).

Despite having earned college degrees as STEM majors from top universities, according to the World Economic Forum (2016), only 26% of jobs in the technology sector are performed by women (World Economic Forum, 2016). The shortage of women employed is glaring on the international landscape (Mozahem et al. 2019). Moreover, the equality and representation of women in STEM fields have been a major plank concerning the political agenda of the United Nations Educational, Scientific and Cultural Organization (UNESCO 2016). The scarcity of women in STEM professions is still high although there has been progress in some STEM disciplines (UNESCO 2016).

Notwithstanding, the major research regarding this study concerns the challenges successful female engineer executives in the oil and gas industry faced in their career trajectories. More importantly, it focuses on their perseverance and resilience in mitigating such challenges. In so much as an "engineer" is a problem-solver by nature, this study shows the problem-solving skills employed by female engineers when faced with adversity.

The theoretical framework that informed the qualitative study of the participating female engineer executives was revealed through the lens of Bandura's (1977) Self-Efficacy Theory. As originated by Bandura (1977), the theory of self-efficacy was highlighted as a framework in which the concept of self-efficacy is attributed to a central role, for analyzing changes achieved in avoidant behavior (Bandura 1977). Concerning the development of STEM interest in these female engineer executives, Bandura asserts self-efficacy beliefs and outcome expectations of an individual influences choice actions by acting indirectly on interests and choice goals (Lent et al. 2000). Lent et al. (2013), suggested a social cognitive career perspective would help clarify career development and choices across the lifespan (Lent et al. 2000). In that vein, the following is literature that supports this body of knowledge regarding early exposure to STEM and career choice.

21st-Century Integrated STEM Learning Experiences

Companies excel largely due to innovative strategies applied to the creativity of their human resources, and the diversification of their workforces (OECD 2018). Yet, the "leaky pipeline" phenomenon, i.e., the diminishing pool of female STEM graduates needed to promote ingenuity and provide solutions for contemporary challenges, accounts for the failure of many women to reach their full potential (OECD 2018). Moreover, while the interest in math and science may be similar in boys and girls as early learners, girls are less likely than boys to choose advanced math and science curriculum in high school, matriculate as STEM majors, or pursue STEM-related careers (OECD 2018). Customized STEM learning experiences tailored to ignite the interest of math and science in girls can offer preparation for the global economy (Shahali et al. 2015). Given STEM education mostly combines problem-solving, critical thinking, and communication skills as a pedagogical strategy, it can improve the scientific and mathematical knowledge of female learners (Shahali et al. 2015). However, teachers' attitudes and beliefs about gender bias also play an important role in the success of females in STEM. Teachers who are unbiased in their teaching styles can play a pivotal role in preparing girls to grasp math and science concepts (Shahali et al. 2015).

Moreover, the Committee on Evaluation of Engineering Education, spearheaded by renowned educator Linton Grinter, issued a clarion call to upgrade engineering education in the U.S. (Miller 2017). In 1955, the Grinter Report established the need for a paradigm shift in the undergraduate engineering curriculum: "Engineering Education must contribute to the development of men who can face new and difficult engineering situations with imagination and competence" (Grinter et al. 1955, 74). By any measure, the shift in the epistemology of engineering has ushered in change in the last half-century (Miller 2017). For example, the engineering of solar energy, virtual reality, cybersecurity, health informatics, nuclear terror, and scientific discovery have rebalanced engineering education as we know it today (Miller 2017).

Similarly, in the 1980s, the "21st Century Skills" movement took hold, yet educators were in a quandary as to moving 21st-century education forward (National Education Association, 2016). Moreover, the National Education Association (NEA) has championed the 21st-century education movement from its inception and advocates for educators to move this agenda as practitioners (NEA 2016). Additionally, NEA helped establish the Partnership for 21st Century Skills (P21) and in 2002 set out on a two-year journey to create the "Framework for 21st Century Learning," that emphasized 18 different skills (NEA 2016).

Over the years, it became clear the framework was too long and complicated, thus, to resolve this issue, leaders from varying roles were interviewed to determine which of the 21st-century skills were the most important for K-12 education (NEA 2016). See Table 1 for the P21 framework for 21st-century learning.

Table 1. The Alignment of 21st-Century Learning Components

P21 framework for 21st century learning			
4C's—Learning and innovation skills	**Information, media, and technology skills**	**Life and career skills**	**Key subjects—3Rs and 21st century themes**
Creativity and innovation	Information literacy	Flexibility and adaptability	Global awareness
Critical thinking and problem solving	Media literacy	Initiative and self-direction	Financial, economic, business and entrepreneurial literacy
Communication	ICT literacy	Social and cross-cultural skills	Civic literacy
Collaboration		Productivity and accountability	Health literacy
		Leadership and responsibility	Environmental literacy
21st century learning design rubrics alignment with P21 framework			
Knowledge construction	Use of ICT	Self-regulation	
Real-world problem solving			
Skilled communication			
Collaboration			

Stehle, S. M., Peters-Burton, E. E. (2019). *Developing student 21st-century skills in selected exemplary inclusive STEM high schools*. *International Journal of STEM Education* 6, 39. https://doi.org/10.1186/s40594-019-0192-1. This image is from an open-access article that allows for use provided the original work is properly cited.

As is apparent in the P21 framework for 21st-century learning and this body of knowledge, honing critical thinking and problem-solving skills contributed to the success of the engineer executives. These engineer executives demonstrated their competence when directing teams on highly technical projects and in interpreting "well" calculations for crude paths to build investment portfolios for oil and gas investors. For example, in evaluating their teams, these engineer executives exhibited insight in assigning the appropriate STEM practitioner to a specific role relative to their background, expertise, and creativity skills. These engineer executives were successful, in part, as they were tactical in mitigating barriers and positioned themselves as competent leaders in understanding the contemporary workplace. Moreover, their STEM constructivist experiences enabled them to apply technical skills and aptly analyze the scope of projects to maximize productivity and profits.

Statistics and the Underperformance of American Children

To create new technologies and provide unique solutions to complex problems, the training and preparations of today's learners regarding innovation challenges ahead is paramount. Taken as a whole, American learners in grades K-12 are underperforming, particularly in STEM subjects. National Assessment of Educational Progress (U.S. Department of Education, 2015a). Scores show in science, only 34% of 8th graders perform at or above proficiency and the number of 12th-grade students at or above proficient U.S. students drops to 22% (U.S. Department of Education 2015a). Correspondingly, mathematics scores show 33% of 8th graders and 22% of 12th graders were at or above proficiency (U.S. Department of Education 2015a). Additionally, the U.S. mathematics scores for the Programme for International Student Assessment (PISA) for 2015 were lower than the scores for 2009 and 2012 (OECD 2018). Moreover, American students not only underachieve in mathematics and science but are not engaging successfully in engineering and technology. At the secondary level, there are relatively few students in the U.S. that take engineering (2%) and computer science (5.7%), respectively (National Science Board, 2016).

This underperformance of American students has sounded alarms to herald national, state, and local efforts to improve learner experiences and outcomes in integrated STEM subjects (Kelley & Knowles 2016). Notwithstanding, these female engineer executives, as early learners, consistently performed at the highest of levels while in K-12 grades and continued their academic prowess while matriculating as engineer majors during college. In consideration for educating the engineer for 2020 and beyond, the following section highlights the initiative of the National Academy of Engineering that addresses the question, "What should engineering core curricula encompass in preparing the next generation of graduates who will assume positions in the engineering profession?"

Engineering Education for the Next Generation

The findings that emerged from a report by the National Academy of Engineering regarding the engineering education for the next generation of engineers suggest: (a) engineering education must produce technically excellent and innovative graduates, (b) there needs to be a development of a clearly defined core curriculum that meets the needs of the institution, (c) a need for skill development which allows for graduates who are better prepared to work in a dynamic global economy, (d) the importance of improving the recruitment and retention of students is essential, and (e) ensuring the learning is experiential and meaningful are critical (National Academy of Engineering [NAE] 2005). Moreover, the report revealed the value of considering changes in engineering education in the broader context of enhancing the status of the engineering profession (NAE 2005). In this vein, constructivist in approach, project-based learning as provided in the next section, it premised on engaging students in investigating real-life problem-solving.

Problem-Based Learning

The concept of project-based learning and teaching has been around for many years and stems in part from the works of Dewey and Kilpatrick (Burlbaw et al. 2013). Yet, in recent decades it has experienced a resurgence resulting from the need for STEM graduates to assume jobs that spur innovation and ingenuity (Hasni et al. 2016). Pedagogies for project-based science learning are built around five features used to design activities that: (a) engage students in investigating a real-life question or problem; (b) result in students developing a series of products that address the problem; (c) enable students to engage in inquiry; (d) involve students, teachers, and members of society in a community of inquiry; and (e) promote students' use of cognitive tools (Hasni et al. 2016).

As such, each of the engineer executives who were interviewed suggested that during their early years, they either attended private schools or those that offered academic rigor. Additionally, they reported that their school curricula were constructivist in nature and promoted critical thinking. Much like the League of Innovative Schools introduced in the next section these engineers were exposed to innovative approaches to problem-solving.

League of Innovative Schools

Created by Digital Promise in 2012, the "League of Innovative Schools" is a membership network of forward-thinking and innovative school district educators in the U.S. (Vo 2017). The leaders of Digital Promise aim to improve outcomes in student learning by collaboratively working with member K-12 school district educators, entrepreneurs, and researchers (Vo 2017). League districts are entrusted to pioneer innovation leaning and leadership practices that prepare learners for life and the workforce. Moreover, membership in the League has proved beneficial as evidenced by the retention rate of member school districts and steady growth (Vo 2017).

Recently, the teaching and learning pedagogy of members has shifted to meeting the individual needs of students through a customized learning model which has resulted in the ability to support learners by offering innovative services and programs and initiatives, especially for girls and underserved students. Moreover, researchers have begun to accumulate practical knowledge regarding the successful use of technology to support learners and strengthen their academic achievement in STEM subjects (V, 2017). Following, are the lived experiences shared by the female engineer executives.

Strategies for Success Employed by Female Engineer Executives at Oil and Gas Companies

Roles, jobs, and industries that have yet to be realized will need to be led by leaders who have acquired extensive training necessary to manage multifaceted and diverse teams in support of their operations. Having built careers with global corporations, the respective female engineer executives were keen at reading the "tea leaves" as they had many years of experience living in countries overseas in both developed and emerging economies (Houston 2019). The ability of these engineer executives to adjust leadership styles and approaches depending on the team or issue was a strength afforded through experience, honed skills, and high-self-efficacy (Houston 2019). Similarly, the "depth and breadth" in which they approached leadership was evident in how they carefully selected and hired those who demonstrated high emotional intelligence and were experts in myriad technologies. Additionally, the engineer executives were in keeping with trends and changing systems, be they companies, industries, countries, or global societies.

Moreover, drivers surrounding moral and ethical issues was a highpoint for these engineer executives as they brought unique perspectives to the decision-making process as members of a historically marginalized group. For example, each of the engineer executives shared their "lived experiences" as females building careers in an inordinately male-predominate industry, e.g., they were commonly overlooked for promotions that were offered to less qualified males to not garnering projects global in scope to gender pay disparity to working within a hostile environment (Houston 2019). Yet each was undaunted and found their "voices" along their career trajectories (Houston 2019). In short, these engineer executives were wholly mindful disruptive technology would require high technical ability and strong analytical skills.

Methodology

For the study in which this research builds upon, the participating subjects were selected through the purposive sampling approach associated with qualitative research (Creswell 2013). Before an interview, each participant was sent via email a "request to participate" letter, an informed consent document, and a copy of the interview protocol. The sample pool included 11 participants who were female engineer executives and one female executive who was a geologist; who held executive-level (vice president or above) positions in the oil and gas industry, inclusive of Fortune 100 oil and gas corporations, petroleum companies, and an energy company. Once the interview process began, the raw data collected were transcribed, coded, and the results reflected data saturation. Data saturation was evident in the consistent commonalities and key themes from responses made by the 12 female executives.

Data Collection and Results

The data collection for this study included a two-phased approach: (a) a comprehensive review of the literature was completed and (b) the conducting of semi-structured open-ended interviews allowed for probing of beliefs and perceptions. The interview protocol was applied to aid in understanding the lived experiences of female engineer executives and the strategies they applied that led to their successful careers. The structuring of participating subjects in semi-structured interviews aligned well with the phenomenological approach where the aim was to examine subjective meanings assigned to concepts by the participant experiences. Additionally, the identity of the participants and corresponding data were kept confidential, and each was identified with an ascribed alphabet to ensure anonymity. Ultimately, the materials of the participating engineers were properly secured, and electronic data was stored on a password-protected laptop.

Findings and Recommendations

Each of the female engineer executives built rewarding and challenging careers in the oil and gas industry, including the petroleum and energy sectors at primarily Fortune 100 companies. The average number of years in which these study participants worked in the oil and gas industry was 25 and the combined years of experience among the 12 participants were 343.5 years. Of further note, giving their many individual years of experience, most of the participants worked for no more than two to three corporations. This is considering the volatility of this industry and the "oil bust" in Houston during the 1980s and early 1990s. Moreover, each of the participants except one had a traditional family including two children (on average), of whom, most were female (Houston 2019).

Each engineer executive was asked 12 open-ended interview questions which enabled the collection of raw data regarding strategies they employed to be successful in the male-dominated engineering field. Despite the challenges which each faced, through resilience, perseverance, and tenacity success steadily became a part of their leadership journeys (Houston 2019). Some of the participants were born into families with little financial means, yet in those instances, their circumstances spurred their will to excel and not succumb to any perceived barriers (Houston 2019). Interestingly, four of the study participants purported they did not experience barriers; and if there were barriers, they employed tactics to mitigate would-be distractions. Conversely, they did share common themes regarding factors they believed contributed to their advancement to executive-level positions in the oil and gas industry. The findings revealed the engineer participants did share common themes to their paths of obtaining an executive-level position, including business sophistication in gleaning how to mitigate barriers. Notwithstanding, successful corporate gender diversity practices will require progressive educational institutions and effective public policy frameworks that enable girls and women to unleash their potential (OECD 2018).

Conclusion

Empowering girls and women through education is a responsibility shared among academia, government, and business, and the success of women in STEM fields will rest on the quality of engagement and collaborative partnership among actors in these arenas (OECD 2018). Efforts should be geared toward enduring engineering projects that are more accessible and attractive to female learners by engaging all learners in interesting, challenging, and innovative projects at all grade levels (Sahin et al. 2015). The dearth of female engineers and STEM professionals, in general, suggests a failure to comprehend an effective solution to a dilemma that can impact the economic standing of Americans in the global market. By passing new legislation, holding leaders accountable, examining organizational policy, and increasing awareness of gender bias and barriers in which female STEM professionals face can enable the full potential of every American. Problem-solving at its core will require an approach that considers social, political, economic, and technological drivers that can harness changes in human behavior on local and global scales. Therefore, it is incumbent upon organizations to invest in their leaders, their technical infrastructure, their data analyzing capabilities, and smart automation or they will soon fall behind the fierce competition.

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