



Engineering Messaging to Tween Girls

A REVIEW OF THE LITERATURE

PREPARED BY THE SOCIETY OF WOMEN ENGINEERS
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Abstract

Efforts to increase the diversity of the engineering profession are often aimed at combatting stereotypes associated with what an engineer looks like and what an engineer does. The messages that are delivered to young people regarding engineering have historically reinforced these stereotypes, intentionally or unintentionally. This report presents a review of the literature on STEM messaging to girls in the age range of 8-13 years old ("tweens"), specifically regarding communications about engineers and engineering. The primary focus is on available research from the last 25 years and the effectiveness of messaging on increasing tween girls' interest and awareness of engineering as a desirable profession. The report also includes a sample listing of websites, videos, programs, and research that are or have been used by girls of this age to increase their interest in STEM, particularly engineering.

Summary of Key Findings

The following points highlight the key findings identified through this review of available literature:

- **Media exposure to engineering can have a positive impact on tween girls' interest in engineering when they combat negative stereotypes and offer examples of female engineers with diverse interests and from diverse backgrounds.**

When adolescents lack direct contact with real-life STEM professionals, media images serve an important role in shaping career perceptions.

Early media exposure can help tween girls become more familiar with what an engineer does and help them see themselves in such roles in the future.

- **Girls are more inclined to hold humanistic values, focusing on people rather than things, and often may not see the impact that engineers can have on society.**

Video interviews with engineers that provide accurate information about the work they do, particularly through personal stories that girls can relate to, can positively influence students' interest in engineering.

Messaging should emphasize the ways in which engineers help people and make a difference in the world.

- **Messages should include a diverse representation of messengers or agents that promote the inclusiveness of the engineering culture.**

Younger agents have been found to be more relatable than older agents among tween girls, and female agents appear to be more effective at influencing girls' beliefs about the utility of math and science.

Agents should not embody STEM stereotypes.

Girls of color are particularly responsive to a diverse cast of messengers. Among Latina youth, language and cultural relevancy are important.

- **Messaging strategies that combine scientific learning and social networking have been effective in engaging tween girls.**

Incorporating social interaction builds on how tween girls use technology in their everyday lives.

Tween girls want messaging that is authentic and relatable, but also shareable.

Introduction

Current efforts to increase the diversity of the engineering profession address both the recruitment and retention of women in STEM. Considering fewer than 3% of college female freshmen indicate an intention to major in engineering, one of the areas of biggest concern is understanding how to encourage more women to enroll in engineering programs in college (National Science Board, 2016). Research supports the importance of developing STEM career aspirations among young people before age 14, with some researchers indicating that many children start thinking about STEM careers before age 11 (Murphy & Beggs, 2005; Tai et al., 2006; Lindahl, 2007). There is little gender difference in student interest and aptitude in science at age 10 (Murphy & Beggs, 2005; Haworth, Dale, & Plomin, 2008), but girls' attitudes experience a negative shift by age 14, particularly towards the physical sciences (Osborne, Simon, & Tytler, 2009). A study by Maltese & Tai (2010) involving interviews with graduate students and scientists found that females were more likely to report that their interest in science came from middle school-related activities rather than self-initiated activities. Social cognitive career theory posits that interest is what drives people's career choice, so if we want to improve gender diversity in engineering then we need to reach girls before they enter high school to encourage their interest in STEM fields (Lent et al., 2002). Students with STEM career aspirations at age 14 are 3.4 times more likely to enroll in a physical science or engineering program in college (Tai et al., 2006).

In 2002, the National Academy of Engineering (NAE) released a report noting the need to improve the effectiveness of communicating to young people about the role that engineers play in society (NAE, 2002). Six years later, the NAE continued its call to present a more effective message of the value of an engineering education in its report, *Changing the Conversation*, stating that the engineering community needed to emphasize the way in which engineers help to improve people's lives rather than in terms of required skills and personal benefits (NAE, 2008). Among girls and women, in particular, the view of STEM occupations as not having a direct societal benefit is impacting their interest in pursuing STEM careers (Hill, Corbett, & St. Rose, 2010; Diekman et al., 2010; Eccles, 1994). This is illustrated in the female enrollment increases seen in degree programs that are viewed as having a societal impact, such as those in the biological sciences, while other STEM disciplines like mechanical and electrical engineering have seen little improvement in gender diversity over time.

To increase the representation of women in engineering, particularly women of color, messaging to girls about engineering must help them see engineering as an inclusive profession. This requires messaging that can encourage and maintain girls' STEM interest through the tween years and into high school. This report provides a review of available literature aimed at answering one main question: What key factors should messaging to tween girls adopt that have been found to be effective in encouraging girls to pursue a career in engineering?

Methodology

While there is not an agreement on the exact definition of "tween," for the purposes of this study tween girls include girls between the ages of 8-13 years old. In developing this report, researchers conducted a keyword search of academic databases and Google Scholar to identify empirical research published in peer-reviewed journals that focus on the impact of messaging on tween girls' interests in STEM. The researchers also searched published and disseminated findings of research funded by the National Science Foundation, non-academic articles, and websites covering media aimed at encouraging interest in STEM among tween girls. Though links to websites, videos, programs, and research are included for further review, inclusion in the resource list is not an indication of the effectiveness or impact of their messaging to tween girls. Rather, the resource list provides examples that could be useful reference for those interested in learning more about current and past efforts to encourage STEM interest in tween girls.

This literature review was developed to inform the creation of effective video messaging to tween girls to encourage interest in engineering. Given that few studies focus specifically on the effective use of video media to middle school girls about engineering, this review considered literature related to a variety of messaging delivery platforms, STEM disciplines, and general marketing strategies that could guide the development of effective engineering messaging to this select group.

Results

This report includes research around four specific areas, and the related literature is categorized under each: the influence of media on reinforcing gender stereotypes, messaging about the engineering profession, research on reaching the tween girls' market, and studies of the effectiveness of messaging strategies. Select reports, websites, and other available media, some of which are mentioned in the Results section, are listed in the Resources section at the end of the report for additional review and analysis.

The Influence of Media on Gender Stereotypes in STEM

The media is very effective at teaching children what the cultural expectations are for boys and girls, men and women. A recent study by Common Sense Media noted that kids begin associating specific occupations and academic subjects with each gender beginning as young as seven years old, based on what they see in movies and on television (Knorr, 2017). Awareness of the unconscious biases that are perpetuated in the media is necessary when trying to combat negative stereotypes that may be influencing girls' decisions to pursue an engineering career. Messaging in spaces commonly occupied or visited by tween girls, including television, movies, online, and in educational spaces, can affect girls' awareness, interest, and understanding of engineering as a profession and its impact on society.

Hill et al. (2010) specify two prevalent stereotypes that continue to impact girls' interest in STEM. First, the idea that girls are not as good at math as boys is one that can undermine girls' aspirations and cause them to disassociate themselves from mathematically demanding programs. Schools and the media have been found to promote this stereotype, portraying math as a gifted rather than developed skill, and its impact has been seen in numerous studies of math achievement (Hill et al., 2010; Dweck, 2008). This has been found to negatively impact women as well as other underrepresented groups, including African Americans and Latinos (Aronson & Steele, 2005; Steele, Spencer, & Aronson, 2002). Research shows that such stereotypes can be nullified by other factors in the environment, which supports the importance of effective messaging tactics to increase female and underrepresented groups in STEM (Good, Aronson, & Harder, 2008; Corbett & Hill, 2015).

The second stereotype discussed by Hill et al. (2010) is the belief that scientific work is better suited to boys and men rather than girls and women. The stereotypical image of the male scientist is one that girls and young women are aware of, and it does negatively affect their interest in pursuing a STEM career (Archer et al., 2012; Buck et al., 2008). A study in the United Kingdom found that when teenagers, regardless of gender, were asked to name famous scientists, they identified Einstein, Newton, and Bell, which indicates a lack of knowledge of any contemporary role models as well as the perception of science as a male-dominated profession (Osborne, Simon, & Collins, 2003). Researchers also noted that science educators are apt to talk more about the scientists, science, and the scientific method rather than what a scientist actually does or share examples of everyday science and scientists. Showing girls examples of female engineers and sharing their real-life stories can help counter negative stereotypes and help them see themselves in such roles in the future.

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Exposure to stereotypical images of STEM professionals can affect girls' interest in STEM because we adopt behavior changes based on the observation and imitation of others – including fictional characters (Bandura, 1977). Steinke (2017) noted that media images of STEM professionals are typically unflattering, unfavorable, and promote the gender stereotype of a white, middle-aged, unattractive, geeky, socially awkward male. Davies et al. (2002) found that gender-stereotypical commercials can undermine women's aspirations and performance in math and science. A Google-Gallup study in 2015 found that students and parents are aware of the lack of female scientists and scientists of color on TV and in the movies, and the ingrained stereotypes around science and scientists may contribute to the lower participation of underrepresented groups. For example, the portrayal of female scientists in the hit series *The Big Bang Theory* is a step forward in promoting gender diversity, while still illustrating the biases experienced by women whose work is devalued or co-opted by male scientists (Weitekamp, 2015). However, when presented with examples of female engineers who do not fit the stereotypical image, there can be pushback from those who take issue with an image that does not conform to their beliefs. The #ILookLikeAnEngineer campaign developed in response to such pushback and went viral across over 50 countries, normalizing non-stereotypical engineers, showing girls that female engineers can be feminine, and celebrating diversity across gender, age, and race (Banchefsky, 2017).

When adolescents lack direct contact with real-life STEM professionals, media images serve an important role in shaping career perceptions (Steinke, 2017; Wasburn, 2007). However, studies of Hollywood films, film biographies of scientists, and international films show that male STEM professionals outnumber female STEM professionals at a ratio of roughly 7.6 to 1 (Weingart et al., 2003; Steinke, 2005; Elena, 1993). A more recent study of 42 popular films featuring female STEM professionals discovered that while more female STEM professionals were portrayed as equal contributing members of research teams, male STEM professionals had twice as many speaking roles compared to female STEM professionals, and there was a greater focus on physical attractiveness and hypersexualization of female STEM characters (Steinke & Tavaréz, 2016). Movie images have also been found to be more memorable than hands-on scientific experiences in shaping adolescents' views of STEM (Barnett et al., 2006; Bhatt et al., 2017).

A study sponsored by the Geena Davis Institute discovered that there were no female protagonists or co-leads with a STEM career in any family films, while STEM males outnumbered STEM females by a ratio of over 5 to 1 (Smith et al., 2012). Also noted was the lack of STEM females in engineering or the applied sciences among a sample of working prime-time characters, while fewer than 10% of female STEM characters in family films were engineers. The study concluded that females are missing from popular media, and when they do appear on screen they are often treated as decoration rather than portrayed in meaningful or prestigious STEM roles (Smith et al., 2012).

Women continue to be underrepresented in science television programs for children and adolescents (Long et al., 2010; Whitelegg et al., 2008), though their presence is increasing in primetime drama programs (Chandler, 2012; Warren et al., 2016). Media images of diverse STEM professionals could increase women's interest in pursuing careers in STEM beyond the life sciences, particularly in applied science fields such as engineering (Kitzinger et al., 2008). Media representations can have an impact on female students' preferences for majoring in a STEM field (Cheryan et al., 2013; Linde, 2011; Myers & Beise, 2001). Studies support the effects of gender-balanced STEM representation in textbooks and videos to moderate negative cultural stereotypes (Good, Woodzicka, & Wingfield, 2010; Murphy, Steele, & Gross, 2007). Research shows that early media exposure to engineering can help tweens become more familiar with what an engineer does, which can in turn help girls become more open to considering engineering as a potential career (Jennings, McIntyre, & Butler, 2015).

Popular media can affect how adolescents view science in general, fueling misconceptions and negative views about science and the scientific community while making STEM careers undesirable (Barnett et al., 2006). Certain STEM disciplines, including engineering, are often seen as having less of a societal impact or community contribution

(Kitzinger et al., 2008; NAE, 2008; Zecharia et al., 2014). Girls are more inclined to hold humanistic values, focusing on people rather than things, and often may not see STEM fields as helping people (Corbett & Hill, 2015; Ceci & Williams, 2011; Lipka, 1998). However, a study of a video intervention supports the impact that such interventions can have on tween views of engineering as a profession that helps people, particularly among girls (Jennings, McIntyre, & Butler, 2015). Video interviews with STEM professionals that provide accurate information about STEM careers can positively influence students' interest in pursuing STEM careers (Robinson & Kenny, 2003; Wyss, Heulskamp, & Siebert, 2012).

A study of fourth through twelfth graders found a significant relationship between gender, age, and the level of interest from students using an online site to ask science questions (Baram-Tsabari et al., 2006). Middle school girls submitted relatively more questions than elementary school girls, and more girls submitted questions than boys in the study. However, most questions from girls were related to the life sciences, which is in line with the stereotypes of girls' STEM interests. Researchers concluded that children's interests in science could be encouraged by promoting self-generated and spontaneous questions through an online platform (Baram-Tsabari et al., 2006). Other studies support the importance of presenting complex information in enjoyable, meaningful, and intrinsically rewarding ways, which can motivate individuals to explore subjects further (Maehr, 1984; McCombs, 1991; Csikszentmihalyi & Hermanson, 1995).

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Numerous programs have been developed to increase school-age girls' awareness, interest, and understanding of engineering, and to ultimately address the lack of gender diversity in the profession. A lot of attention has been paid to combating stereotypes and assumptions that proliferate in our culture through the media, online, and in educational spaces. Specifically, programs and services have been developed targeting girls in middle and high school to encourage them to consider an engineering career. However, some efforts have been more successful than others.

A campaign by the European Commission to persuade teenage girls to become scientists launched with a video entitled *Science: It's a girl thing!* in 2012 (can be viewed here: <https://www.youtube.com/watch?v=GMOqpxlW66E>). Unfortunately, the gender roles in the video only helped to promote the stereotypes of female scientists found in popular culture: women in short skirts and stilettos in the lab focusing on the science of make-up (Rice, 2012). The video was quickly removed from the campaign site, and while some teenagers commented that they appreciated seeing that scientists could express their femininity, the organization's future efforts were more focused on gender inclusiveness in STEM (Hypatia Project, 2017).

A study by Steinke (2004) that reviewed science and engineering websites targeted at girls considered the information presented, how and in what style it was presented, and how female scientists and engineers were portrayed. She notes that biographies of female STEM role models may be an effective way to reach a large number of girls to make them aware of their career options. Steinke cautioned against highlighting certain realities of some engineering workplaces, including discrimination, racism, sexist attitudes, and long hours, which may dissuade girls from pursuing engineering careers. However, other researchers note that girls will attribute female role models' successes overcoming these realities to perseverance and hard work (Weisgram & Bigler, 2007; Frome, Alfeld, Eccles, & Barber, 2006).

Girls are more interested in role models who share personal stories that girls can relate to, as well as how their career helps make the community or the world a better place (Sammet & Kekelis, 2016). Researchers note that girls are typically drawn to engineering disciplines that present opportunities for altruistic and nurturing pursuits (Colvin et al., 2013; Bystydzienski & Brown, 2012). Communications to girls about who makes a good engineer should emphasize the actual work that is done rather than a need to "love" math and science or portraying engineering as a challenging career (Sahr & Hebshie, 2008).

Bystydzienski & Brown's (2012) study of high school girls observed that the majority of girls who recognized gendered recruitment practices (websites that present girls for show rather than engaged in engineering work, use language about "caring" and "helping", and non-engineering women promoting engineering for girls) and were skeptical of the attempts to portray engineering as welcoming to women were mostly White or Asian Americans of high socioeconomic status. Research indicates that girls are less drawn to STEM careers when the person serving as a role model embodies STEM stereotypes, regardless of whether the role model is male or female (Cheryan et al., 2011). One case study found that inspiration for STEM-related careers arose from success in science experiences outside of school in ways that positioned girls as smart, capable, and powerful (Tan et al., 2013). Girls should be encouraged to engage in authentic science practices rather than solely being recognized for giving right answers and obtaining high grades in science, as girls who appear to be high achieving in science may actually be at risk of losing interest (Tan et al., 2013; Murphy & Beggs, 2005; Brickhouse, Lowery, & Schultz, 2000).

As tween girls progress through middle school, their views and affiliations with STEM are impacted by the norms, rules, resources, and practices of the multiple worlds they inhabit (Carlone et al., 2011). Their identities and interactions with others affect how they engage in STEM activities (Calabrese Barton et al., 2013). Language and cultural relevancy are important in working with Latina youth, and students benefit from studying the achievements of STEM professionals that reflect aspects of their background that they can relate to so they understand that they have options (Wilson-Lopez, 2016; Daisey & José-Kampfner, 2002; Carrico, 2013). Archer et al. (2010) discussed the dilemma in helping children identify with science because of how constructs interplay across various identities, including gender, ethnicity, and social class. As such, science can be communicated in ways that boys may find "too feminine" and girls may find "too masculine."

Research suggests that the characteristics of the messenger or agent interacting with tweens could influence their motivation and connection with the subject. Bandura (1986) and Baylor (2009) found that the appearance of the messenger could influence the observer more than just the voice of the messenger, particularly when the agent is of the same gender and same ethnicity/race. However, some research indicates that students in middle school, regardless of gender, may see female agents as powerful role models in engineering. A study by Ashby Plant et al. (2009) found that girls' interest in engineering increased after being shown a 20-minute narrative delivered by a computer-generated female agent. In the video, a young and attractive computer-generated agent (either male or female) described the lives of female engineers while counteracting stereotypes of engineers as antisocial, emphasizing the people-oriented and socially beneficial aspects of engineering. Researchers found that the female agent was more effective in influencing students' beliefs about the utility of math and the hard sciences, regardless of students' gender. The researchers noted that their findings indicated that interventions designed to support female students might benefit both genders.

Studies on changing girls' views about engineering recommend that interventions involve diverse representatives to combat existing stereotypes and illustrate that the engineering culture is inclusive (Cheryan, Master, & Meltzoff, 2015; Steinke, 2003). In studies of the use of multiple anthropomorphic virtual agents of different gender and race among college students, researchers have found that students learn significantly more and had significantly greater motivation when working with more than one agent (Baylor & Ebberts, 2003; Baylor & Kim, 2005). A recent experiment involving middle school students and the use of an animated pedagogical agent found that the age of the agent has an impact on the treatment effect (Ozogul, Reisslein, & Johnson, 2011). When using a peer agent versus an adult agent, the young agent had a greater effect on students' learning. This aligns with findings from previous studies on students' inclination to model and imitate people that are more like themselves, including peers (Azmitia & Cooper, 2001; Kindermann, 2007; Crosnoe et al., 2008).

The National Science Foundation published two books containing overviews of grant-funded projects involving gender diversity in STEM. The first, *New Formulas for America's Workforce: Girls in Science and Engineering*, was released in 2003 and covered over 200 grant projects from 1993 through 2001. The second, *New Formulas for America's Workforce 2*, provided descriptions of approximately 100 additional grants made from 2002 through 2005. In addition to a general listing of sample resources, the Resources section of this report includes projects from these two books that could potentially inform the development of messaging to tween girls.

Marketing to Tween Girls

In addition to literature on past and current programs aimed at attracting girls to STEM careers, available market research on tween girls could inform the development of effective messaging about engineering to girls of this age group. This section focuses on literature and research associated with general marketing efforts to tween girls, highlighting strategies that have been found to be effective in reaching this audience.

The Lego Group, the makers of a toy that historically has been sold with boys in mind, launched a product line in 2012 aimed at 5-12 year old girls after conducting years of market research (Trangbaek, 2013). Unlike previously failed attempts to tap into the female market, Lego Friends has helped the company's profits grow an average of 15% annually since its debut (LaFrance, 2016). What market researchers had learned from their studies of how girls and boys play is that girls are much more interested in building environments than single structures, which traditional Lego kits typically allow. The Lego Friends line differs from traditional sets by offering girls a chance to build structures and develop interesting stories involving these structures through role-play. While the decision to offer these products in colors and styles that many consider "stereotypically girly" has been criticized by some, the sharp increase in sales to girls since the product lines launched has resulted in Lego becoming the world's largest toy manufacturer in 2017, an indication of the company's successful marketing strategy (LaFrance, 2016; Op4G, 2017). This research on understanding the differences in how girls and boys play indicates the inclusion of a storytelling or interactive aspect to STEM messaging might help to encourage girls' interest.

The Pineapple Lounge, an agency that focuses on kids and family market research, conducted a study of tween girls to find out what they like and dislike about various brands. Researchers found a big difference between girls ages 8-10, 11-12, and 13-14 in levels of confidence, how they communicate, favorite school subjects, and interest in technology (Chahal, 2015). Marketing to girls requires appealing to their individuality, as a girl's sense of self and desire for empowerment grows with age. The study included a look at GoldieBlox, a brand that makes toys and entertainment for girls to encourage them to become engineers. Girls in the study indicated that, while girls enjoy pink and princesses, they welcome messaging that combats stereotypes and "showed girls in a positive way".

A recent study on the tween consumer market found that having access to infinite knowledge through technology encourages them to act older than their chronological age, resulting in "age compression" that drives them to seek media that reflects a mature interpretation of their lives (Baird & Witt, 2017). Researchers recommend that messaging to tweens be "strategically and appropriately" created to offer a look and feel for an audience that is 2-3 years older, and avoid the perception of being "too babyish." Tweens are attuned to social movements and current events much more than in previous generations. Regarding the media platform, about 70% of tween and teen smartphone users spend at least three hours per day watching videos on their phones (Baird & Witt, 2017). Organizations must ensure that video delivery is not sluggish and that videos are of short duration, as most tweens and teens indicate that they usually watch videos under 10 minutes in length (Chester, 2017; Baird & Witt, 2017). Tweens respond to messaging that is authentic, relatable, and shareable. They value instant gratification, so live streaming is a popular method of engaging tween viewers – particularly those that allow tweens to share, express themselves, and connect with peers (Baird & Witt, 2017).

Impact and Effectiveness of Engineering Messaging

Available research on the effectiveness and impact of messaging campaigns and techniques is limited. Campaigns are launched, programs are initiated, but few organizations are measuring the effectiveness of their efforts – possibly due to the difficulties in separating out the impact of one initiative among many on girls' long-term interest in a STEM career. This section discusses some of the research that has been done on the effectiveness of STEM messaging to girls, with particular attention to efforts that utilize video or website platforms to encourage engineering interest.

Verizon, in partnership with Makers, launched "Inspire Her Mind" in 2014. Broadly aimed at encouraging girls interest in STEM, the campaign reached out to parents of girls to make them think about how their words and actions can help deter their daughters from considering a STEM career. According to AKQA, the creators of the advertisement launched on behalf of Verizon to remind parents that "girls aren't just pretty but 'pretty brilliant,'" the advertisement has had over 320 million total views and drew praise from many high-profile women in STEM (AKQA, 2017). Though directed at parents, it is important to remember that young girls are heavily influenced by parental attitudes and beliefs about STEM (Eccles, 1994; Steinke, 2004).

Microsoft launched the #MakeWhatsNext campaign four years ago. The campaign includes videos to encourage girls to consider a STEM career. In 2017, Microsoft released a resource for girls interested in STEM that allows girls to consider how they can tie their interests and goals to various industries and social causes (Stanley, 2017). Called MakeWhatsNext.com, the site is aimed at keeping girls interested in STEM by allowing them to explore and learn about STEM careers. A case study on the use of Instagram to market their #MakeWhatsNext campaign noted that they potentially reached 91 million people and received 3.5 million total likes on related photos (Mediakix, 2017). Experts noted that one reason for the campaign's success was that it centered on stories of real human experiences that audiences could connect and engage with (Mediakix, 2017).

One of the first virtual worlds created around science education for kids is *Whyville*. When a 2011 case study was conducted, the site had almost 7 million members, and 76% of those members were female – with tween girls among its highest users (Grimes & Fields, 2012). Researchers found that social interactions with others were a draw for most players, as well as a strong design culture that allows players to design their own avatars. While many other sites have since appeared in the digital learning market, and *Whyville* may not be as popular as it was a few years ago, it is an example of how scientific reasoning and social networking can be combined in a way that tween girls enjoy.

The WGBH organization has launched multiple initiatives targeted to children and teens to encourage interest in STEM, particularly engineering. The Extraordinary Women Engineers project, a national initiative led by various engineering associations and the WGBH Educational Foundation, formed in 2004 to encourage girls to consider an engineering career. The group also investigated the effectiveness of existing messaging to girls and messaging opportunities to increase interest, particularly among high school girls, to pursue engineering careers. Survey responses from girls noted that current engineering messages that portray engineering as challenging, stressful, and requiring strong math and science skills are not effective. Rather, researchers discovered that girls react positively to personal and informational stories of current engineers, with the most effective messages using examples that contain multiple career motivators, including a good working environment, making a difference, and flexibility (EWE, 2005).

An impact study of another WGBH initiative, the PBS reality television series *Design Squad*, included an evaluation of the use of video animations, live action videos, and video profiles on increasing middle school students' knowledge and interest in engineering. The researchers discovered that students exposed to *Design Squad* developed a better understanding of what engineering is and the types of projects that engineers might work on, and they demonstrated

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more positive attitudes towards engineering compared to students who were not exposed to *Design Squad* (Paulsen & Bransfield, 2010a). Researchers noted that utilizing strong outreach partnerships helped *Design Squad* reach a widespread audience, including traditionally underserved audiences (ethnic minorities, girls, and low income children).

Studies of the impact that *SciGirls*, a national television series and website created to engage and educate children on science topics, have found that exposure to the television episodes and website activities had a positive influence on the interest of fifth grade girls in science and robotics (Flagg, 2012; Flagg, 2013). A 2016 study of ethnically diverse fifth grade girls measured the impact of exposure to *SciGirls* videos and online games on girls' interest in citizen science programs (Flagg, 2016). Researchers found that girls who were exposed to *SciGirls* programming prior to the introduction of a citizen science program expressed higher interest in the program than girls who were not exposed to the *SciGirls* programming. They also discovered that girls of color related more to the diverse cast of female youth in the videos than white girls, and girls of color also expressed significantly stronger interest in the *SciGirls* programming and in finding out more about other citizen science projects. These findings support prior research that indicates that ethnically diverse youth are more responsive to vicarious experiences than their white counterparts (Usher & Pajares, 2009).

A formative evaluation of *Latina SciGirls*, programming filmed in Spanish and featuring Hispanic girls and Hispanic STEM mentors, discovered that while the girls found the characters in *Latina SciGirls* likeable and good role models, some girls stated that they did not relate well to the characters because (1) the girls were not interested in technology, (2) the girls did not typically speak Spanish with their friends, (3) the girls were younger or less mature than the *Latina SciGirls* characters, and (4) the characters were from different countries than the viewers (Knight-Williams et al., 2017). Girls also expressed interest in combining Spanish and English in the programming (Knight-Williams et al., 2016).

After releasing its *Changing the Conversation* report in 2008, the NAE followed up with a call to action. The organization recommended promoting new messaging to cast engineering as creative, concerned with human welfare, and emotionally satisfying (NAE, 2012). The *Engineer Your Life* campaign aimed at encouraging girls to explore engineering worked with NAE to inform its messaging, focusing on three messages: (1) creativity has its rewards, (2) explore the possibilities, and (3) make a world of difference (Sahr & Hebshie, 2008). Originally aimed at high school girls, the *Engineer Your Life* website has been incorporated into the *EngineerGirl!* website. Utilizing what they learned from the Extraordinary Women Engineers project, the initiative used a communication strategy that focused on the societal value and rewards of being an engineer through websites, webinars, social media, and advertisements. A service of the NAE, the website provides contests, activities, and message boards for girls and women of all ages to encourage greater female participation in engineering. A 2009 survey found that almost 70% of middle school girls intended to visit the *EngineerGirl!* site again, and a similar number planned to share the site with others (Jenniches & Didion, 2009). An evaluation of the program in 2010 that reviewed feedback from high school girls, counselors, and engineers found that the *Engineer Your Life* initiative had a significant impact on the target population who used their resources. The resources filled an information gap, with young women reporting that they became more interested in engineering after visiting the *Engineer Your Life* website (Paulsen & Bransfield, 2010b). However, the most commonly reported barrier from active engineers who provided feedback was that young women lack familiarity with the engineering industry, which may indicate that the messaging is effective when it reaches the target audience, but getting girls to participate and listen to the messages is a challenge.

Summary of Main Findings

A review of available literature was conducted to identify the key factors of effective messaging to tween girls that will encourage them to pursue a career in engineering. However, the available literature on effective STEM messaging to tween girls, specifically messaging aimed at encouraging girls to consider an engineering career, was surprisingly limited. This review did uncover a few key findings that may inform the development of effective engineering messaging to tween girls.

The role of media, including movies, television, and online spaces, in reinforcing gender stereotypes in STEM is a major issue. While more women are being portrayed in STEM professions onscreen, there is a need for more positive images of STEM professionals that do not fit stereotypical images. To encourage more girls to consider engineering, research shows that media exposure to engineering can have a positive impact on tween girls' interest when that exposure combats negative stereotypes and offers examples of female engineers with diverse interests and from diverse backgrounds. This is particularly important for girls who lack direct contact with real-life STEM professionals, as media images serve an important role in shaping their career perceptions of engineers. It is also important to reach girls at a young age, as many children's STEM career aspirations are set before high school. Early media exposure can help tween girls become more familiar with engineering and provide diverse role models that encourage them to see themselves as engineers.

Certain STEM disciplines, such as those in the biological sciences, have seen improvements in gender diversity. Many researchers believe that this is primarily due to girls' desire to pursue a career that has a direct societal impact. Girls are more inclined to hold humanistic values, focusing on people rather than things, and often may not see the impact that engineers can have on society. Video interviews with engineers who provide accurate information about engineering, including the ways in which engineers help people, can have a positive impact on girls' interest in pursuing an engineering career. However, there is some disagreement among researchers about how much truth should be shared, as some indicate that highlighting the existence of discrimination, racism, and sexism in the workplace may deter girls from engineering while others believe that it may emphasize the importance of perseverance and hard work. Above all, role models should share personal stories that girls can relate to, stressing the ways in which engineers help to make the world a better place.

Research on the impact of messenger or agent characteristics on message effectiveness, particularly in regards to gender, race/ethnicity, or age of the agent, discuss the benefits of having diverse representatives to combat existing stereotypes and promote the inclusiveness of the engineering culture. Generally, engineering messages should include agents that are relatable to the audience. Younger agents have been shown to be more relatable than older agents. Among Latina youth, language and cultural relevancy are important. Agents should not embody STEM stereotypes, and female agents appear to be more effective at influencing girls' beliefs about the utility of math and science. It may be beneficial to have more than one messenger, which provides an opportunity to include diverse role models in messaging to tween girls. Though some of the research included in this review involved the use of virtual agents, this information gained from these studies may be useful in developing messaging using real people.

Available research on the tween girls market identified some successful marketing strategies that companies have used to entice girls' purchasing and brand loyalty, and this knowledge may be useful in informing the development of effective engineering messaging to reach this market. Tween girls respond to messages that combat gender stereotypes and address their desire for empowerment, which grows with age, even within the short span of the tween years. In a similar vein to the academic research that shows that girls focus on people rather than things, the market research indicates that girls enjoy opportunities for interaction and storytelling. Programs that combine scientific learning and

social networking have been particularly popular among this age group. Given the rapid advancements in technology, tweens are more attuned to social movements and current events, and they seek immediate gratification. Also, experts indicate that centering on stories of real human experiences that audiences can connect and engage with are effective ways to reach young girls.

Studies on the effectiveness of engineering messaging to girls are few, but those that have been done support the findings from academic and market researchers. Incorporating social networking into a messaging program has been found to be an effective way to interest and engage tween girls in STEM activities. Personal and informative stories from real engineers are also effective, particularly those that allow engineers to discuss the types of projects that they work on. Tween girls respond positively to a diverse cast of messengers, and this is particularly true for girls of color. Developers of messaging to Latina girls should be aware of the cultural differences within the Hispanic culture because Latina girls may find characters who are from other countries less relatable. Regarding language, Latina girls have indicated an interest in messages that combine Spanish and English.

Overall, the research indicates the importance of presenting information about engineers and engineering in an enjoyable, meaningful, and intrinsically rewarding way. Today's tween girls respond favorably to messaging that incorporates social interaction with science learning that is easily accessible and relatable. Hence, video messages that are short, authentic, relatable, and shareable may be most effective in engaging this demographic and encouraging their interest in engineering.

Conclusion

This review of available literature on effective engineering messaging to tween girls required a broad look at literature on STEM stereotypes, STEM messaging, and general market research. There were a number of areas in which the academic research and the market research overlapped, offering supportive evidence in effective strategies to reach the tween girl audience. The programs and projects listed in the Resources section of this report include examples of ways in which individuals and organizations have used these strategies to reach tween girls, including the use of diverse female engineers in messaging, illustrating ways in which engineers help people and make a difference in the world, and presenting complex STEM information in enjoyable, meaningful, and socially engaging ways.

Resources

The following resources are presented as examples of messaging aimed at encouraging girls to pursue engineering studies and careers. In some cases, the resource is applicable to a broad audience that includes tween girls, while other are specifically aimed at this narrow audience. They are organized in four categories: Sites specifically aimed at encouraging girls' interest in STEM, sites aimed at young people that could influence girls' interest in STEM, recent research and activities that could inform the development of effective messaging to girls, and inactive sites that could serve as useful references.

Active campaigns, websites, programs, and videos aimed at encouraging girls' interest in STEM, including tween girls:

RESOURCE	NOTES	LOCATION
EngineerGirl!	A service of the NAE, the website provides contests, activities, and message boards for girls and women of all ages to encourage greater female participation in engineering.	https://www.engineergirl.org/
SciGirls from DragonflyTV	The site offers outreach resources, educator guides, videos, and an interactive website to interest elementary and middle school girls in STEM. Some videos are offered in Spanish (Latina SciGirls).	In NSF's New Formulas for America's Workforce 2 (pg. 25) http://pbskids.org/scigirls/
Whyville.net	An interactive science-oriented website with over 100 games and a virtual world for a community of learners.	In NSF's New Formulas for America's Workforce (pg. 102) http://www.whyville.net/smmk/nice
Radio Series Tells the Stories about Girls and Women in Science	Radio stories aimed at helping increase girls' and women's participation in STEM.	In NSF's New Formulas for America's Workforce 2 (pg. 4) http://wamc.org/term/women-science-air-0
Amy Poehler's Smart Girls #STEM10	Videos that highlight young entrepreneurs. The video series is presented by CA Technologies.	https://amysmartgirls.com/what-is-stem10-135b079b4e39
"Invent It Build It 2016"	Video about the Society of Women Engineers' annual outreach event.	https://www.youtube.com/watch?v=GmLLE-9f6sg&t=4s
"SWENext Club Winners"	Videos by the Society of Women Engineers of a SWENext Reporter interviewing the winners of various 2017 SWENext challenges and Ariel Biggs, the Invent It Build It MC (race car driver).	https://www.youtube.com/watch?v=e9asua3oxPM&feature=youtu.be https://www.youtube.com/watch?v=y_5yFjFkoj4&feature=youtu.be https://www.youtube.com/watch?v=R sC3XackFBI&feature=youtu.be
"SWENext Design Lab"	Video about a Society of Women Engineers' outreach event aimed at middle school girls.	https://www.youtube.com/watch?v=Y u1uOGrgUno&feature=youtu.be

RESOURCE	NOTES	LOCATION
"Meet Our 2017 SWENext Global Innovator Award Recipients"	Video highlighting the seven girls that received the Society of Women Engineers' 2017 SWENext Global Innovator Award, explaining their winning projects.	https://www.youtube.com/watch?v=54Nzv-eHD4k&feature=youtu.be
"Inspiring the next generation of females"	A TEDx Talk by Debbi Sterling, an engineer and founder of GoldieBlox, a toy company out to inspire the next generation of female engineers, with some toys and books aimed at 6-9 year olds.	https://www.youtube.com/watch?v=FEeTLopLkEo https://www.goldieblox.com/ - website to order toys. Includes a blog and apps.
"Introduce a Girl to Engineer Day"	A video aimed at girls that compares engineers to superheroes. The video highlights female engineers whose research helps people and society. Includes interviews with a diverse group of young girls.	https://www.youtube.com/watch?v=tCSnKOhzjcc&feature=youtu.be&list=PLvzOwE5lWqhRwq-tbR2lidLcoBd3XUe_s
"Introduce a Girl to Engineer Day: STEAM"	A video by the SWE Chapter at Drexel University that tells girls that they can practice an "arts-integrated approach to engineering and mathematics".	https://www.youtube.com/watch?v=tCSnKOhzjcc&feature=youtu.be&list=PLvzOwE5lWqhRwq-tbR2lidLcoBd3XUe_s
Project Lead the Way videos	Videos aimed at students, many specifically to girls, to encourage them to consider engineering.	https://www.youtube.com/user/TeamPLTW/videos?shelf_id=8&view=0&sort=p
TECHNOLOchicas	An NCWIT initiative to raise awareness among Latinas about technology careers	https://technolochicas.org/camp https://technolochicas.org/videos
Roadtrip Nation STEM videos	Videos that educators can share with middle and high school girls centered on STEM career exploration through interviews with STEM professionals	http://roadtripnation.com/roadtrip/women-in-stem#show
"Black Girls Code"	A TEDx Talk by Kimberly Bryant, the founder of Black Girls Code. The nonprofit introduces programming and technology to girls of color between the ages of 7-17.	https://www.youtube.com/watch?v=TJ-m47CxAl0 http://blackgirlscode.org/
Tech Girls Movement	An Australian nonprofit organization promoting positive female IT role models for girls. The site includes videos of interviews with inspiring women in STEM. Research papers are also available on the site.	http://www.techgirlsmovement.org/

RESOURCES

RESOURCE	NOTES	LOCATION
#LetGirlsLearn STEM in Egypt	This video includes three girls talking about pursuing STEM in Egypt.	https://www.youtube.com/watch?v=75bGZtbr-Aw
“Why We Need More Women in Science”	A video by Kina McAllister, founder of StemBox, a toy company that creates science kits for girls that foster an emotional connection to STEM.	https://mystembox.com/about

Active STEM campaigns, websites, programs, and videos aimed at encouraging young people to consider STEM careers, and that may inform effective messaging to tween girls:

RESOURCE	NOTES	LOCATION
SciShow	Videos that explore scientific subjects to encourage kids’ interests in science. The channel has over four million subscribers.	https://www.youtube.com/channel/UCZYTClx2T1of7BRZ86-8fow
Born to Engineer	A British campaign aimed at inspiring young people to become engineers. The site includes a number of videos highlighting engineers of various races, genders, and disciplines.	https://www.borntoengineer.com/video
The Hypatia Project	An EU Horizon 2020 funded project to promote gender-inclusiveness in STEM. Includes ready-to-use modules for teachers, organizations, and industry.	http://www.expecteverything.eu/hypatia/
PBS Kids Design Squad Global	Includes videos and activities for middle schoolers (girls and boys) to encourage interest in engineering. Videos feature kid engineers and hosts/role models to dispel stereotypes about engineering.	http://pbskids.org/designsquad/
Microsoft YouthSparks	Microsoft provides resources to increase young people’s (particularly girls) access to computer science education	https://www.microsoft.com/about/philanthropies/youthspark/youth-sparkhub/makewhatsnext/
“What is Engineering?” and other videos	Videos created by the engineering faculty at the University of Newcastle (Australia) to demystify engineering professions using animations.	https://www.youtube.com/playlist?list=PLjt5Y3Djaldx8Q0bxySh9w9hE57W-mAXGB

Recent research or activities that may inform the development of effective video messaging to tween girls:

RESOURCE	NOTES	LOCATION
WISE, a UK organization that supports women in STEM, issued 10 white papers in March 2008	The papers focus on the media's impact on the role and image of women in STEM.	https://www.wisecampaign.org.uk/resources/2008/03
nPower Girls	A program for middle school teachers to spark girls' curiosity in STEM. May have resources.	https://web3.esd112.org/stem-initiatives/npower-girls
STEM is Cool! video contest entries	Change the Equation challenged companies to create videos featuring employees using math or science in exciting or unexpected ways.	http://www.changetheequation.org/stem-cool
DiscoverE videos	DiscoverE provides various resources, including videos, to help educators and volunteers engage students	http://www.discovere.org/discover-engineering/cool-engineering-projects
"STEM Careers - Why aren't kids interested in them?"	A video by Randstad USA that illustrates the need to educate kids about what STEM professionals actually do. If they don't know what the careers are about, how will they know if they will be interested in them?	https://www.youtube.com/watch?v=HxuEHHERFIQ

Inactive campaigns, websites, programs, and projects that may be useful references:

RESOURCE	NOTES	LOCATION
Dot Diva	Dot Diva's mission is to create an exciting and positive image of computing for high school girls.	http://dotdiva.org/index.html NOTE: The material on this site is not being updated.
The Image of Engineering	A company called Imaginary Lines (also known as Sally Ride Science) created two videos and two companion books aimed at encouraging upper elementary and middle school girls to pursue STEM.	In NSF's New Formulas for America's Workforce 2 (pg. 6)
Girls and Information Technology: A Promotional Video	The Center for Women and Information Technology at the University of Maryland-Baltimore County developed a short video about women's ability to succeed in careers.	In NSF's New Formulas for America's Workforce 2 (pg. 17)
Imagination Place	EDC's Center for Children and Technology developed an interactive online design space for girls ages 8-14 in the early 1990s.	In NSF's New Formulas for America's Workforce (pg. 77) http://cct.edc.org/publications/role-gender-design-electronic-learning-environments-children : An article about the role of gender in designing electronic learning environments, based on the outcomes of the NSF project.
Media Literacy Training for Middle School Students	The aim is to learn whether media literacy training teaches children to recognize and resist gender stereotypes	In NSF's New Formulas for America's Workforce 2 (pg. 6)
Engineering Lessons in Animated Cartoons	A project aimed at attracting children of all ages through a multimedia presentation, including seven cartoon movies.	In NSF's New Formulas for America's Workforce (pg. 85)
Plugged In! An Interactive Science Website	A Girl Scout-led project to create an interactive, graphics-intensive science website for girls.	In NSF's New Formulas for America's Workforce (pg. 106)
Radio Series on Alaskan Women in Science	A five-part radio series profiling five Alaskan women in STEM.	In NSF's New Formulas for America's Workforce (pg. 158)

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