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Dare to imagine

"STEM for Girls"

Engaging girls in mixed group STEM challenges

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Executive Summary

To address the STEM skills shortage and the gender gap, with just 16.5% of engineers being female, we need to use evidence to understand how to best engage girls when delivering mixed gender STEM challenges.

STEM for Girls is a practical research programme that aims to identify activities and methods of engagement that give girls a more positive view of STEM and of their future in it. The research is funded by the Thomas Gerald Gray Charitable Trust and consists of the literature review, followed by a primary research phase taking some of the recommendations to test in schools.

This document lays out insights from articles, reports and academic journals, and makes recommendations based on those insights to enhance STEM activities in order to better-engage girls and encourage them to consider engineering as a career.

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KEY FINDINGS:

This literature review finds that there are significant biological, psychological and social differences between boys and girls which impact on girls' engagement with STEM activities and career aspirations:

- Biological differences in hearing and vision have implications for the design and delivery for STEM content for girls

- Gender-bias and stereotypes have a strong impact on girls' attitudes towards STEM and directly challenging these is shown to have a positive impact on STEM career aspirations

- Girls strongly prioritise helping and working with others in career aspirations and may be more attracted to these areas within engineering careers if they were made aware of them

- Girls' confidence, self-belief and attitude towards STEM subjects decreases as they get older. Interventions should be focused on changing girls' beliefs before they become embedded

A key area to investigate further is the use of role models:

- Female role models have a positive impact on girls' engagement

- Girls view girls as being just as successful in STEM subjects as boys, yet women being less successful than men, suggesting there is a disconnect between how girls view themselves and women

- Exploring role model groups that exhibit a range of ages, particularly transitional ages, rather than single woman role models may help to bridge this gap in girls' perception

KEY RECOMMENDATIONS:

Following the literature review, the key recommendations for engaging girls in mixed group STEM challenges are as follows:

1. Design resources in a way that will engage girls, especially including colour, facial expressions and images of girls and women in STEM.

2. Use specific techniques when delivering content to engage and encourage girls, including use of tone and volume.

3. Engage female role models of different ages in order to bridge the gap between girls and the women they will become.

4. Directly address and challenge gender stereotypes in mixed-group STEM sessions.

5. Intervene early in girls' lives before negative stereotypes and low self-confidence in STEM subjects are embedded.

6. Emphasise the social applications of STEM and the broadness of STEM careers.

Introduction

CONTEXT:

There continues to be a STEM skills shortage, which the IET estimate costs the UK economy around £1.5bn a year, and a gender gap, with just 16.5% of engineers being female. These challenges impact the UK's prosperity and mean young people are missing out on skilled employment and potentially pioneering new technologies.

To address the shortage, we need to reach out to all young people and show them the possibilities of a career in engineering, which is the focus of The Smallpeice Trust's charitable activities. From a young age, there is a significant difference between the perceptions of engineering between boys and girls. By the time they reach secondary school only 35% of girls think engineering careers fit well with them.

Each year, Smallpeice delivers STEM Challenge Days in schools to over 20,000 students, around 50% of these being girls. Given the significant differences in perception, and the current gender gap, more needs to be done to reach girls in these mixed gender environments. The literature review forms the first stage of new research to address this, with key insights identified then being taken to the field and tested as part of Smallpeice's STEM challenges.

The Smallpeice Trust is grateful to the Thomas Gerald Grey Charitable Trust for funding this research.

ABOUT THIS REVIEW:

STEM for Girls is a practical research programme that aims to identify activities and methods of engagement that give girls a more positive view of STEM and of their future in it. This literature review aims to lay out insights from articles, reports and academic journals and make recommendations based on those insights to enhance STEM activities in order to better-engage girls and encourage them to consider engineering as a career.

RESEARCH QUESTIONS:

- How do young people's perceptions of STEM and STEM careers correlate with their gender?

- How does the engagement of young people vary according to the make-up of the enrichment activity they are participating in, and how does this correlate with their gender?

- What are the most effective activities, techniques, and communication strategies to engage girls in STEM, and engineering in particular?

- What actionable insights can be drawn from research to design engagement activities that are particularly impactful on girls' interest in STEM, and engineering in particular?

- How do the developmental periods and milestones of females and males affect their relative disposition towards STEM, and engineering in particular? The critical points where divergence could arise between the attitudes of females and males to STEM include: age, puberty, educational transitions, etc.

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NOTE ON GENDER IDENTITY:

We acknowledge that gender identity is nuanced and that not all individuals align to the categories of 'male' and 'female'. For the purposes of this review, we will focus on girls and women due to the gender imbalances present within the engineering workforce. Where gendered or sexed terms (e.g., "girl/woman", "female") are used in reference to research results, these reflect the use of such terms in the original research.

Review of Literature

There are many ways that gender has an impact on our behaviour. There are biological, psychological and social factors which impact on girls' and women's tendencies to engage in STEM.

Initially, this review aimed to group literature by these themes; however, it is impossible to fully isolate the impact of an engagement strategy into biological, psychological, or social components as there is feedback between all three areas. The overlap was significant and therefore the literature has not been split into the three categories, but grouped more loosely by related themes.
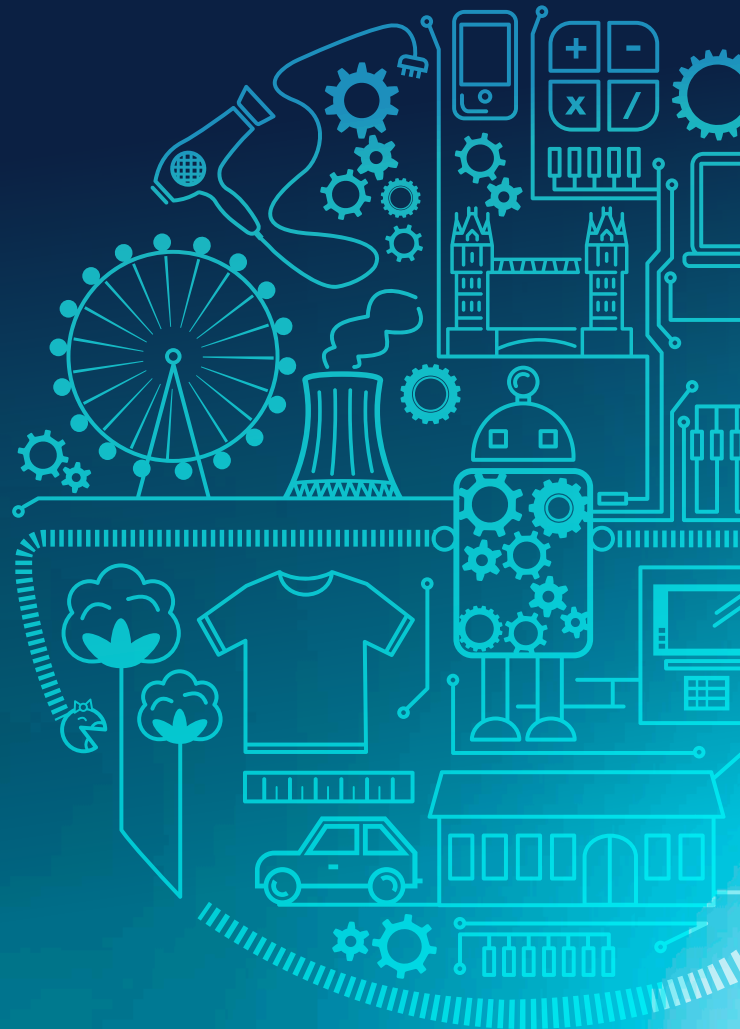
Gender Differences and Student Engagement (2018)

INSIGHTS

Studies show that there are biological differences between girls' and boys' hearing: girl babies hear a 1,500 Hz tone about 80% greater than the average baby boy does. Demonstrations show that noise levels which distract 11-year-old girls are 10 times softer than for boys. As such, girls won't learn as well in a loud environment. Furthermore, a male teacher speaking in a tone of voice normal to him, may appear as yelling to the girl in the front row. Conversely, males need a loud voice to gain their attention and will do better at the front of the classroom, where their ability to pay attention increases.

There are also biological differences in eyesight: a girl's retina is built differently from a boy's. Evidence suggests girls are more drawn to colour images as their colour vision is better. In another study, 102 babies were given a choice between looking at a simple dangling mobile or at the face of a woman who smiled but didn't speak. Boys were more than twice as likely to prefer the moving mobile, while the girls were drawn to the living face.

Evidence shows that although girls are willing to take risks, they are less likely to seek out risk-taking behaviour. They also underestimate their abilities, whereas boys overestimate theirs, and girls will be less likely to engage in an activity where they have no experience compared to boys. Moderate stress improves boys' test performance, but degrades girls' performance.

Girls are suited to small group learning, as they are more comfortable asking a teacher for help if needed and are more responsive to tone of voice and intention when asking for help.

RECOMMENDATIONS

- Use colour resources, including characters and photos that show faces to draw girls' attention to materials
- Train deliverers to tailor their speech to the sex of the student, speaking louder for boys and quieter for girls, with more emphasis on tone
- Aim to minimise stress for females and add competitive stress for males
- Encourage girls to engage in activities they are unfamiliar with
- Organise activities in small groups to engage girls
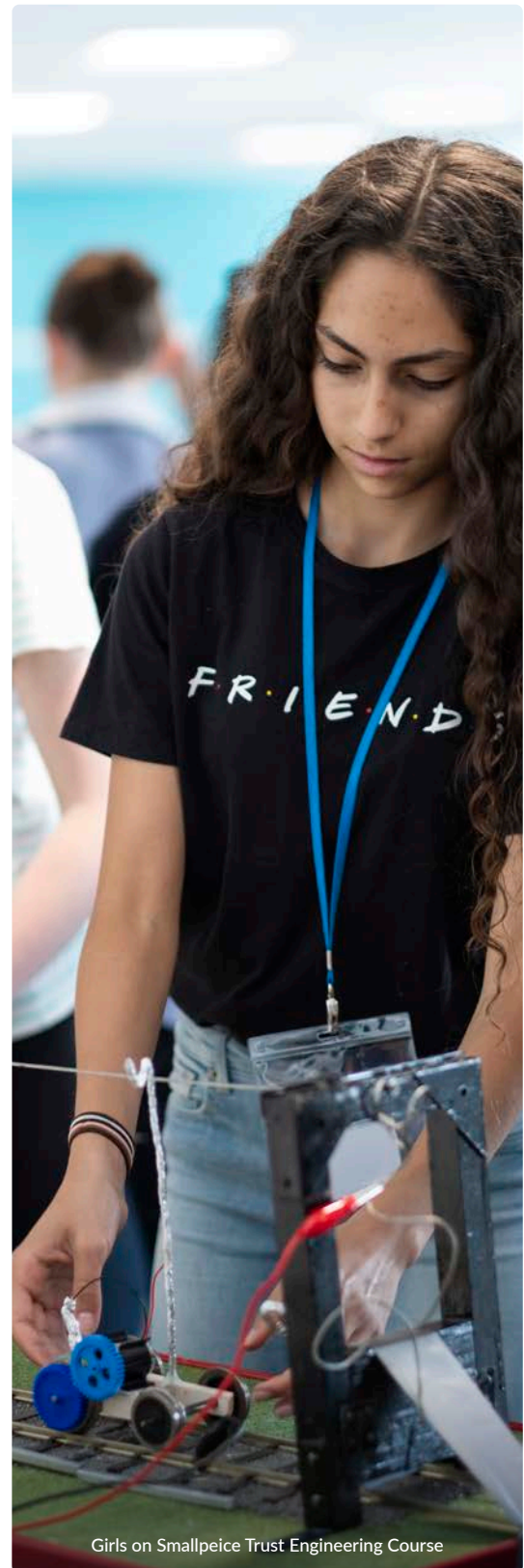
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Infant Perception of Sex Differences in Biological Motion Displays (2019), Sex-related differences in vision are heterogeneous (2018), Why Men and Women See Things Differently (2012)

INSIGHTS

The differences in vision and visual processing between the sexes has been extensively researched; however, the results have varied. Precise insights would require thorough analysis, which is beyond the scope of this review. However, the main consensus appears that:

- Male vision is generally higher-contrast, while female colour-vision is better

- Males are better at motion detection (better reaction time)

RECOMMENDATIONS

- There are no specific recommendations; however, where opportunities exist to differentiate activities for males and females, the female activity could have a stronger focus on colour and a diminished focus on motion, and vice versa for males

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Keeping Girls in STEM: 3 Barriers, 3 Solutions (2019)

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INSIGHTS

The research found that girls underperform on multiple choice tests as they are less likely to guess than boys. However, girls perform better with open-ended answers.

RECOMMENDATIONS

Use more open-ended questions, and fewer multiple-choice questions

If using multiple-choice questions:

- Explicitly encourage making guesses based on judgement calls

- Design questions to have a ramp up in the level of 'risk' from making guesses, so it's non-threatening

The effects of gender stereotypic and counter-stereotypic textbook images on science performance

(2010)

This study included 81 US students, 13-17 years-old (29 male, 52 female), who read one of three chemistry lessons, each containing the same text, with photograph content varied according to stereotype condition: either all-female, all-male, or a mix of female and male scientists. Students then completed a comprehension test and anxiety measure.

INSIGHTS

The results showed that female students had higher levels of comprehension after viewing the counter-stereotypical images which included female scientists compared to viewing stereotypical images of male scientists.

RECOMMENDATIONS

- Include imagery of girls and women working in STEM in resources

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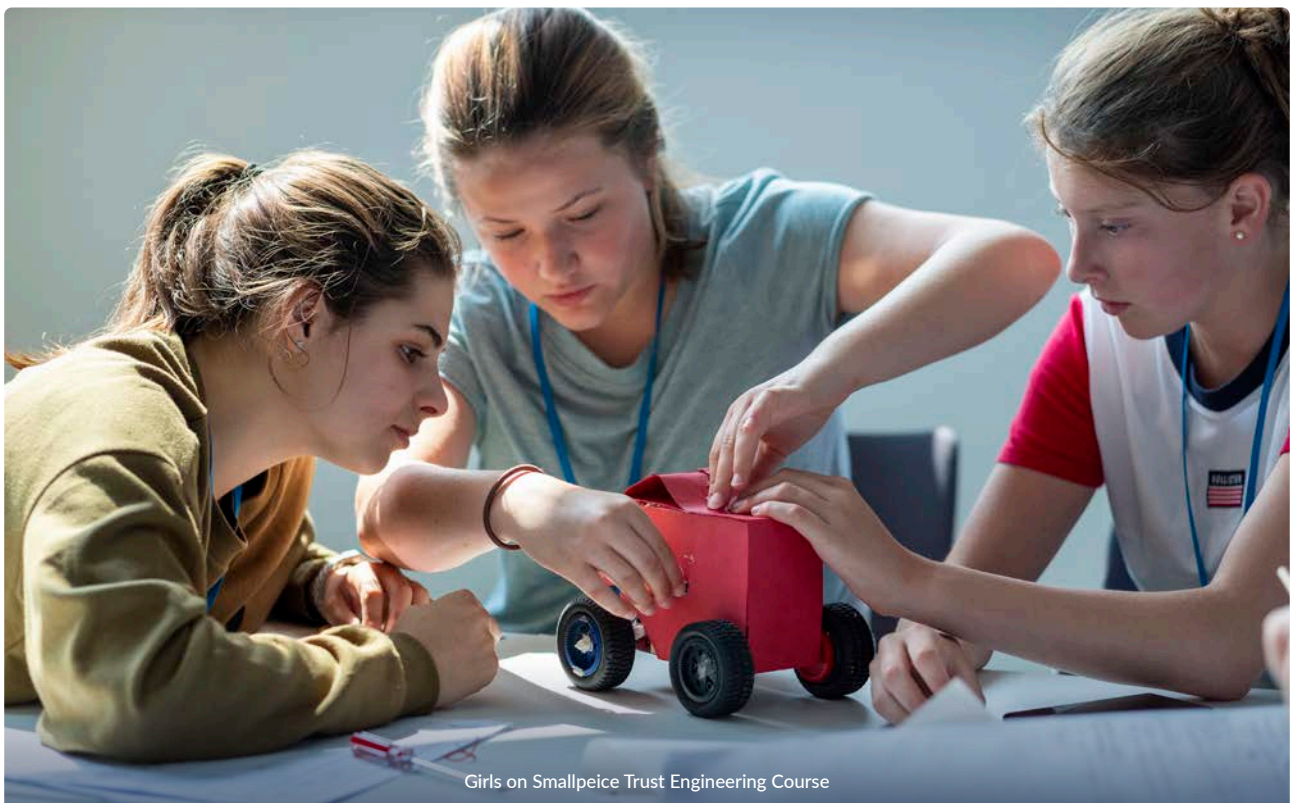
Girls in STEM:
Is it a Female Role-Model Thing? (2020)

This study evaluates the impact of a maths role-model intervention on 304 Spanish girls, 12-16 years old, in which female volunteers working in STEM visited schools to talk to girls about their careers.

INSIGHTS

The study focussed on girls aged 12 and above as this is the age when girls' self-confidence and self-perception of their competence begins to fall. The results showed that female role-model sessions had a significantly positive effect on girls' mathematics enjoyment, expectations of success and girls' aspirations in STEM. They also had a negative impact on gender stereotypes and significantly increased the girls' expectations of success in STEM choices. The study showed that the more counter-stereotypical the content of the sessions, the higher girls' expectations of success in maths and the choice of STEM subjects. When young girls perceived that counter-stereotypical skills, including teamwork, communication and social skills, are required for different STEM professions, this positively impacted their intention to pursue a STEM career.

RECOMMENDATIONS

- Research and intervention should be focused on young girls, before their self-confidence falls and negative self-perception begins

- Address stereotypes about STEM directly: the more a session challenges the stereotypes of girls in STEM, the greater the impact of the session on engagement in STEM and STEM careers

- Emphasise counter-stereotypical skills, like teamwork, communication and social skills, required for engineering careers

- Expose young girls to the professional and personal experiences of female role models with a successful trajectory in STEM careers

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Children's Gender Stereotypes About Math:
The Role of Stereotype Stratification (2006)

This study included 42, largely white, middle-to-upper class, US public school 1-4th grade girls who were asked to complete some sorting and drawing activities. Students sorted pictures of people by gender, and then sorted pictures of maths problems into the gender piles. Students were also asked to draw a character to match the story they were told. The experiments were controlled for experimenter gender by a rough 50:50 split by gender of experimenters present, and rotation of roles between sessions.

INSIGHTS

Girls overall placed advanced maths images with males more often than basic maths images. They rated men as both liking and being better at maths than women, but viewed boys and girls as being equal on these variables. Additionally, girls were more likely to draw a man when told a story about an adult mathematician; however, were more likely to draw a girl when told of a child mathematician.

The researchers theorised that girls made more-positive associations with maths for themselves than they do for women in general because they did not see themselves as part of the 'woman' group yet. They also suggested that this view was reinforced by the stereotypical view that women are less STEM-capable, and the reality that fewer women work in STEM careers.

As girls grow into women, they may adopt the stereotype that women as less STEM-capable than men; however, while they are young, they may think of themselves as being part of a distinct group ('girls'), that are equality good at STEM.

RECOMMENDATIONS

Explore role model groups that exhibit a range of ages, particularly transitional ages (e.g., teenage), rather than single woman role models. This may bridge the gap between young girls' perceptions of girls' abilities in STEM compared with women's, helping to erase negative stereotypes of women in STEM.

Put another way, a "We like STEM" model, that connects a girl in stages to who she is going to be, may be more impactful than an "I like STEM model", that involves a woman role model that girls may see as being from a different group to themselves.

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Why So Few?
Women in Science, Technology, Engineering, and Mathematics (2010)
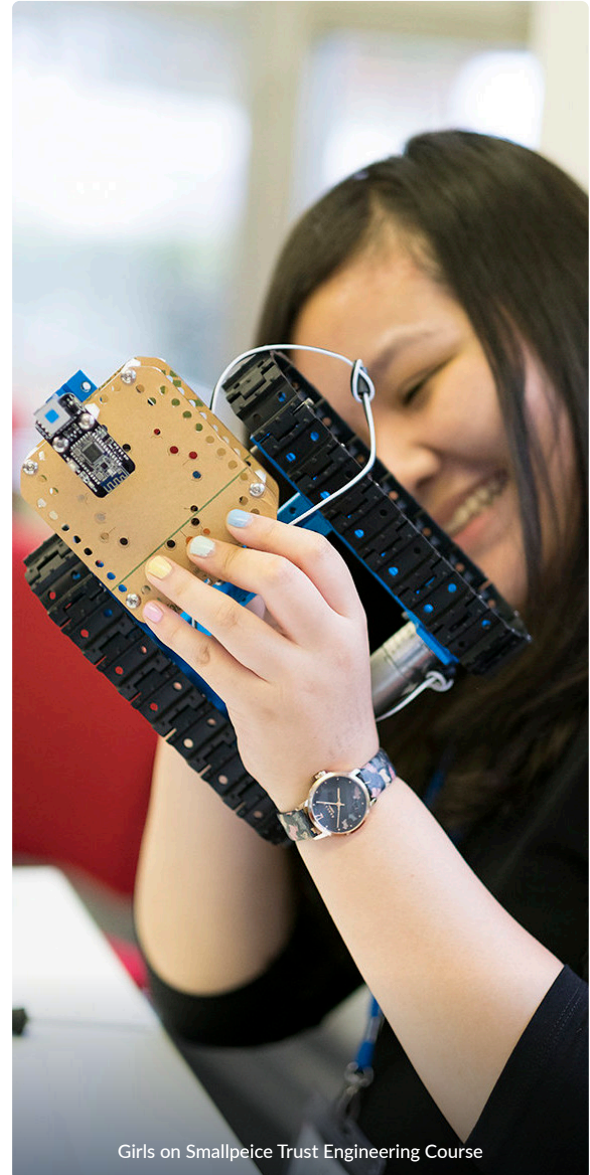
INSIGHTS

Research found that girls' achievements and interests in STEM areas are shaped by their environment and societal beliefs. Generally, people judge women as less competent than men in 'male' jobs unless they are clearly successful in their job. However, when a woman is clearly competent in a 'masculine' job, she is considered less likable. Research shows that negative stereotypes about girls' ability in maths can negatively impact their test performance. Girls also appear to underestimate their ability compared to boys: they assess their mathematical abilities lower than boys with a similar mathematical achievement. However, when teachers and parents foster a 'growth mindset' and tell girls that their intelligence can expand with experience, their performance on maths tests improves.

Research shows the importance of spatial skills within engineering study and that males consistently outperform females in this area. However, this can be rectified with short, simple interventions. Therefore, if girls have effective spatial skills training as they grow up, this enhances their success in STEM subjects, especially engineering.

RECOMMENDATIONS

- Tell girls that their intelligence can expand with experience and learning - create a 'growth mindset'
- Tell students that girls and boys are equally capable
- Challenge negative perceptions of women in STEM roles
- Incorporate spatial training and exercises into STEM content

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The STEM Gap:
Women and Girls in Science, Technology, Engineering, and Mathematics (2023)

INSIGHTS

This research summarises the key factors perpetuating gender STEM gaps:

- Gender Stereotypes: STEM areas and occupations are often viewed as masculine, and parents and teachers often underestimate girls' abilities in maths, starting as early as preschool

- Male-Dominated Cultures: As a result of a gender imbalance in STEM careers and study, these fields tend to perpetuate exclusionary, inflexible, male-dominated cultures which do not support or attract women

- Fewer Role Models: Girls are exposed to limited examples of female scientists and engineers in books, media and popular culture and have fewer role models, especially Black women role models in maths and science

- Maths Anxiety: Teachers, who are predominantly female, often have maths anxiety which they pass onto girls. They also often grade girls harder for the same work, and assume girls need to work harder to achieve the same level as boys

RECOMMENDATIONS

- Raise awareness that girls and women are as capable as boys, especially in STEM areas

- Develop a 'growth mindset' which encourages girls to embrace challenges and recognise that abilities are not fixed, but develop over time

- Highlight strong and visible women role models

- Connect STEM experiences to girls' lives, promoting active, hands-on learning and emphasising how STEM is collaborative and community-oriented

- Increase girls' awareness of higher education, pathway opportunities, career opportunities, female role models and mentoring programs with women in STEM

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Solving the Equation:
The Variables for Women's Success in Engineering and Computing (2015)

INSIGHTS

Research shows that overall, both men and women have similar gender biases and strongly associate science with male areas. However, when split into different fields, researchers found that men studying STEM areas such as engineering and computing had strong implicit science-male biases, whereas women in the same field had weak implicit science-male biases. Conversely, in non-scientific fields the situation was reversed, and women had much stronger science-male biases than men did. This demonstrates that implicit biases are not set. Although it is not clear whether women's weaker science-male bias came before or after the choice to work in STEM, these studies illuminate a strong relationship between women's implicit biases and the pursuit and attainment of STEM degrees. Female role models in engineering and computing can help shift implicit biases for both women and men.

Another study found that women are more likely than men to prioritise helping and working with other people over other career goals. Therefore, the perception that engineering occupations lack opportunities to work with and help others may partly explain why women are underrepresented in these fields. Studies suggest that communicating the opportunities within engineering careers for achieving communal goals and social purpose may have more success in attracting women.

RECOMMENDATIONS

- Acknowledge the reality that we are all influenced by gender biases, whether or not we consciously endorse them

- Expose girls to female role models working in STEM

- Showcase the social purpose of engineering: talk about the ways that engineers and computing professionals solve problems for society, which are the ultimate goals of engineering and technology

- Emphasise the social aspects of engineering, including teamwork

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EngineeringUK briefing:
Gender disparity in engineering (2018)

INSIGHTS

There is a disconnect between what girls believe an engineering career offers and the things that are important to them. Girls were more likely than boys to:

- value making a difference / having an impact (+8 percentage points)

- value being valued (+8 percentage points)

- value being creative (+9 percentage points)

Girls are less likely to think they could be an engineer if they wanted to and see that being an engineer would 'fit well with who they are'. Things that drive this could be:

- Fears of not being clever enough

- Not wanting to be the only girl in the class

- Having to change their personality to fit in

Despite girls' lower perceptions of self-efficacy, evidence shows they outperform boys at STEM subjects.

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RECOMMENDATIONS

- Highlight where STEM careers incorporate values that girls are strongly aligned to, including the social applications of engineering

- Directly challenge the stereotypes within STEM

EngineeringUK Engineering Brand Monitor (2019)

INSIGHTS

EngineeringUK analysis clearly shows that young people who know more about what engineers do are more likely to perceive the profession positively and to consider a career in the industry. Girls are more likely to describe the profession as: 'too complicated or difficult'; 'dirty, greasy or messy'; and 'a career for men'. Almost half (48%) of girls aged 14-16 reported they knew 'almost nothing' or 'a little' about engineering, compared to 31% of their male peers.

Girls are also significantly less likely than boys to consider a career in engineering. For those 11-14, only 46% of girls reported they would consider a career in engineering, compared to 70% of boys. Furthermore, girls aged 16-19 were even less likely (25%) to ever consider a career in engineering. This shows the importance of early intervention.

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RECOMMENDATIONS

- Challenge girls' narrow view of engineering and expand their awareness of careers in STEM

- Intervene at a young age to challenge negative perceptions towards engineering as a career

Key Insights

- Girls' experiences differ from boys' due to biological, psychological, and social factors

- Females typically have better colour vision than males, while being less adept at detecting contrast or motion, and are more attracted to images including faces

- Females typically have more sensitive hearing at frequencies important to speech

- Girls are less likely to take risks, guess or engage in an activity where they have no experience

- Gender-bias and stereotypes have a strong impact on girls' attitudes towards STEM

- Girls and women strongly prioritise helping and working with other people and the social impacts of careers

- Counter-stereotypical content, such as the importance of teamwork, communication and social skills, in STEM interventions has a positive correlation with girls' engagement with STEM and future career ambitions

- Women role models significantly increase girls' positive expectations of STEM success

- Girls' performance in academic tasks can be boosted by seeing images of women in relevant STEM-related settings

- Girls can believe they are as capable as boys at STEM subjects while also believing women to be less capable than men

- Girls' self-confidence and self-perception of competence declines from age 12 onwards

- The likelihood of girls considering a career in STEM decreases as they get older

Key Recommendations

Developing resources:

o Use colour to communicate

o Use images including faces

o Use imagery of girls/women, especially in settings and performing activities that are STEM-related

o Incorporate spatial training and exercises into STEM content

Delivery of content:

o Speak more quietly to females than males, as they are biologically more sensitive to speech sounds

o Speak to females with a greater emphasis on tone

o Encourage girls to try new activities and to make guesses based on judgement calls

Use a range of role models:

o Engage female role models of a range of ages, bridging the time gap between girls and the women they will become (e.g., for teenagers, involve role models that are still in school, have recently left school, are in training, and are in different stages of their careers)

Address gender stereotypes:

o Address stereotypes about STEM directly: explain explicitly that they exist and that you are challenging them

o Raise awareness that girls and women are as capable as boys and men

o Create a 'growth mindset' by telling girls that their intelligence can expand with experience and learning

Start young:

o Intervene early in girls' lives to challenge stereotypes and low self-confidence in STEM before they are embedded

Emphasise the social applications of STEM:

o Raise awareness of the breadth of careers in STEM and the counter-stereotypical skills required, such a teamwork, communication and social skills

o Raise girls' awareness of the social applications of STEM careers

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