Not just girls who do science, but scientists: smashing glass ceilings in the science classroom

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Abstract Interest in and motivation to tackle the physical sciences often wanes as girls enter high school. The message that science is for boys remains powerful in certain sectors of society. This article reflects on observations of the science classroom culture in girls' schools in South Africa (which may manifest in other countries as well). Societal norms seem to influence the vulnerability girls feel in taking risks in science, and lack of confidence in their scientific abilities. Small modifications in pedagogy by educators and advocating acts of courage in the science classroom are suggested as possible solutions to empowering more girls to embrace science and confidently take their place in society as scientists.

One of my favourite genres of books when I was a child was anything medical, involving hospitals and doctors and nurses. I announced to my family one day that I was going to be a nurse when I grew up. Knowing my penchant for all things medical, my Mom asked, why a nurse and not a doctor? My reply: '*I'm a girl*'. Such was the patriarchal society I grew up in in the 1970s and 1980s. In all the books I read, the doctors were male and the nurses were female. This was part of our socialisation and my consciousness.

I chose science teaching as a career and have spent over 30 years teaching at vastly different high schools. I currently teach at St Mary's Diocesan School for Girls, a sought-after independent school for girls in KwaZulu-Natal, South Africa. It is a school that actively encourages the girls to be curious, think critically and to develop the courage, character and confidence to thrive in life. I believe that girls often limit their ambitions around careers in STEM, and they are under-represented in STEM careers partly because of the myth that science is a boy's domain. There have been numerous articles written about the 'gendered brain', as we live in a gendered world. Although the tide is slowly turning, with research shattering that myth (Rippon, 2019), the message that science is not for girls remains powerful.

I have realised that we science educators have the power to help shift societal norms and beliefs by modifying our pedagogy in nuanced ways to build girls up to believe that they are true scientists. I would like to share some of my observations and experiences over the years of teaching girls. This is not intended to be a rigorous empirical study in which sets of data are analysed and evaluated, but rather my reflections on my own experiences and conversations with many other science teachers of girls in my country, and some possible solutions. For an in-depth study that highlights the impact that classroom culture has on male and female students' career expectations, I recommend the study by Janina Beckmann (2021).

The influence of societal norms

In primary school, most girls are interested in science: they love and appreciate the wonderment of science exploration and are open to taking risks. Yet this interest and motivation often seems to wane as girls enter high school. They are shaped by subtle cultural messages of male superiority in the sciences, to value perfection, and avoid risk at all costs, resulting in an under-representation of girls taking physical science as a subject, and following careers in STEM. This is even more prevalent in a school that does not actively encourage and advocate the growth mindset.

In our physical sciences department, we have found that several of the girls in our classes are not prepared to take risks in answering questions, even though the classes are small. We find that when girls do take risks in answering questions, they often start their answer with '*I don't think this is right, but* …' I conducted a survey among the grade 10–12 (ages 15–17) science students in our school, and some of their answers floored me. It seems many of them have the notion that to take risks in class in answering or asking questions is to open themselves up to judgement and condemnation by other girls. Competition between girls, even in the science class, is rife. Why do girls feel the need to do this? I wonder if the nature of the subject, which is seen as challenging for girls, has something to do with this? Perhaps, on some subconscious level, the entrenched legacy of female exclusion in science or the scarcity of the roles available to them to succeed in this field fuels their self-doubt and fear of exposure of their weaknesses.

Feedback after assessments

In our department we assess fairly often in the senior grades, both formatively and summatively. We find it is a constructive process, helping the students to identify misconceptions and providing opportunities for further learning. When I hand back any assessment after it has been graded, I take time to explain that giving back and going over work is not a shaming exercise, but a valuable tool where we discover where there are conceptual problems or where more precision and accuracy could have been afforded to explanations and calculations. I take a whole lesson to go over the assessment in detail, providing thorough feedback, and the girls are encouraged to use these tests as a revision tool in the learning process and in preparing for an examination.

Every time I hand back an assessment, a significant number of girls turn their papers face down on the desk, without even looking at the grade. They take minutes to gather up the courage to slowly turn over the corner of their paper and peek at their grade. They feel ashamed, as if their grade is linked to their self-worth. What is the solution to this? My colleagues and I have discussed whether writing the grade at the end of the script would make a difference, or perhaps not even writing the grade at all on the script. Perhaps going over the test in detail before giving the papers back would alleviate this, although I believe that if students have evidence of their incorrect work in front of them, the feedback process is much more meaningful, as they can correct their specific mistakes for later reflection. I want them to understand the rationale behind the grading in a particular question.

Learned helplessness

We find that even girls who are high achievers do not generally have a lot of confidence when it comes to science. Some have remarked that the questions in tests and examinations are much more difficult than those they have tackled in class. This is puzzling, as we model our questions on examples they have done in class, other than providing a different scenario or application. These girls are battling to apply the principles they have learnt and practised in class to problem-solving in a test situation. They come into the test feeling that, if they have prepared properly (which most do), there should be nothing that they have not seen before.

Are we unknowingly enabling '*learned helplessness*' (Seligman and Maier, 1967), whereby there is the perception by some students that tests or examinations set are so difficult that they believe that the results are beyond their control? This lack of confidence in taking ownership of the outcome of difficult questions is a learned behaviour. The fear of the unknown in problem-solving is so great that students are conditioned to believe that it is beyond their reach, leading them to behave in a helpless manner. This can escalate over the years of their journey in science, affecting their levels of resilience.

Possible solutions

The way forward is to help our girls to increase their levels of confidence and belief in their scientific abilities so that they can compete competently and effectively. I believe it is with small modifications in our pedagogy that we will start to make a difference.

Making learning fun

I wonder if one of the reasons why I was not that confident in my scientific abilities when I chose a career is that my learning was highly theoretical, and not much fun, with few real-world applications; my curiosity was certainly not sparked to any great extent. When students take ownership of their learning, when they play a role in the learning process and the construction of their knowledge, confidence will grow.

If new concepts are introduced with a fun exploration task, so that the students can see the real-life value in what they are studying, students will be invested in their learning. Students should always be reminded of the *why*.

I decided to introduce Newton's first law of motion with a fun challenge outdoors, involving teams racing with filled containers of water. Each competitor stood behind a stool on which was placed an open container filled to the brim with water. On my '*go!*', they each picked up the container of water and walked/ran as quickly as possible to a point where I abruptly shouted '*stop!*' We repeated the exercise, to confirm and validate observations. The girls squealed with joy and delight at this task. In our discussion afterwards, the girls noted that when the competitors started, and picked up the water containers, the water sloshed out *backwards*. When they stopped abruptly, the water sloshed out *forwards*. This was such a fun way to introduce the concept of inertia. It was the springboard for animated discussion for the whole lesson, and it crystallised their understanding of other applications of Newton's first law (Figures 1–3).

Questioning and methods of evaluation

I have observed that many girls feel intimidated when they are put on the spot to answer a question, mainly for fear of being shamed in front of their peers. However, if these students are not directly engaged and encouraged to think about an answer, it is all too easy to let others in the class answer. I believe that well-framed questions can serve

Figure 1 The girls set off with containers filled to the brim with water. The water has considerable mass and therefore inertia. As they start to move *forwards*, the water in the containers stays behind as it tries to maintain its state of rest, and can be seen spilling *backwards* out of the containers.

Figure 2 This shows the short course over which the girls moved to the stopping point. The speed of movement and deceleration are different for all three girls, which affected the amount of water that spilt out of the containers.

as powerful metacognition tools and are the key to sparking curiosity. Questions could be framed so that they are more open-ended, asked in such a way as to provide clues so there is inference. These clues could provide scaffolding or building blocks towards a logical sequence so that there is incremental learning and mastery, leading the students to a willingness to take greater risks in answering. Even if a student provides an 'incorrect' answer, she

Figure 3 The girls each came to rest at slightly different times. The girl in the foreground of the picture has stopped completely and suddenly, so the water container also stops moving. The water in the container resists the change and carries on moving owing to its inertia, and therefore spills *forwards* out of the container. The girl in the centre has reduced speed more gently and spilled only a little water. The girl in the background decelerated even more gently and managed not to spill any water.

could be probed as to why she is thinking like that. It is up to us educators to make this as important a learning opportunity as only discussing the correct answer. Focusing on cognitive *progression* rather than outcome will go a long way to building confidence in our girls. In that vein, it is perhaps important to often break the class up into pairs and small groups and present them with a challenging task over which they can exchange ideas and have the courage to offer their opinion: the so-called 'Think-Pair-Share' strategy (Frank Lyman, 1981). Creating opportunities for girls to engage in challenging tasks collaboratively, to make mistakes together and to try to find solutions as a team, provides positive messages about competence and a solid foundation to build on when cognitively grappling with problems on their own.

Growth mindset

One strategy we as educators can adopt is to help girls believe that their scientific ability is dynamic and can be developed and improved upon with practice. If we

promote a growth mindset in our girls, we can normalise effort over ability. We should also normalise what Eduardo Briceño (2015) calls 'stretch' and 'aha-moment' mistakes. Scientific ability can grow over time with rigorous practice and a strategy to follow. Where lack of confidence in taking ownership of learning is a learned behaviour, so, I believe, is courage. The more we practise courage the more courageous we become; courage is being willing to take risks and hence make mistakes. We need to help our girls step out of their comfort zone, to be vulnerable, and to consistently practise acts of courage in the science classroom: '*Vulnerability … is having the courage to show up and be seen when we have no control over the outcome. Vulnerability is not weakness; it's our greatest measure of courage*' (Brown, 2015).

Role models and mentors

Girls need to be increasingly exposed to successful female role models and mentors in STEM. All of us are shaped to some degree by influential figures in our lives. Getting in local female scientists, especially former students of the school, to chat to the girls and hopefully inspire them, is a good start. Older students, peers, family and friends can also be powerful mentors and influential figures in STEM empowerment for girls. The classroom is a microcosm of society: if we can normalise the celebration of well-known and famous scientists, as athletes and entertainment-industry celebrities are celebrated, we can normalise it into the fabric and culture of our society.

I consider myself fortunate to teach in a school for girls, to be a part of rewriting the narrative of gender linked with scientific ability. I am committed to empowering girls to embrace science with confidence and to providing tools to smash those glass ceilings. I am committed to helping girls unlearn behaviour and norms associated with gender roles, and to transform gender-stereotypical versions of themselves. These are not just girls who do science. These are scientists.

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