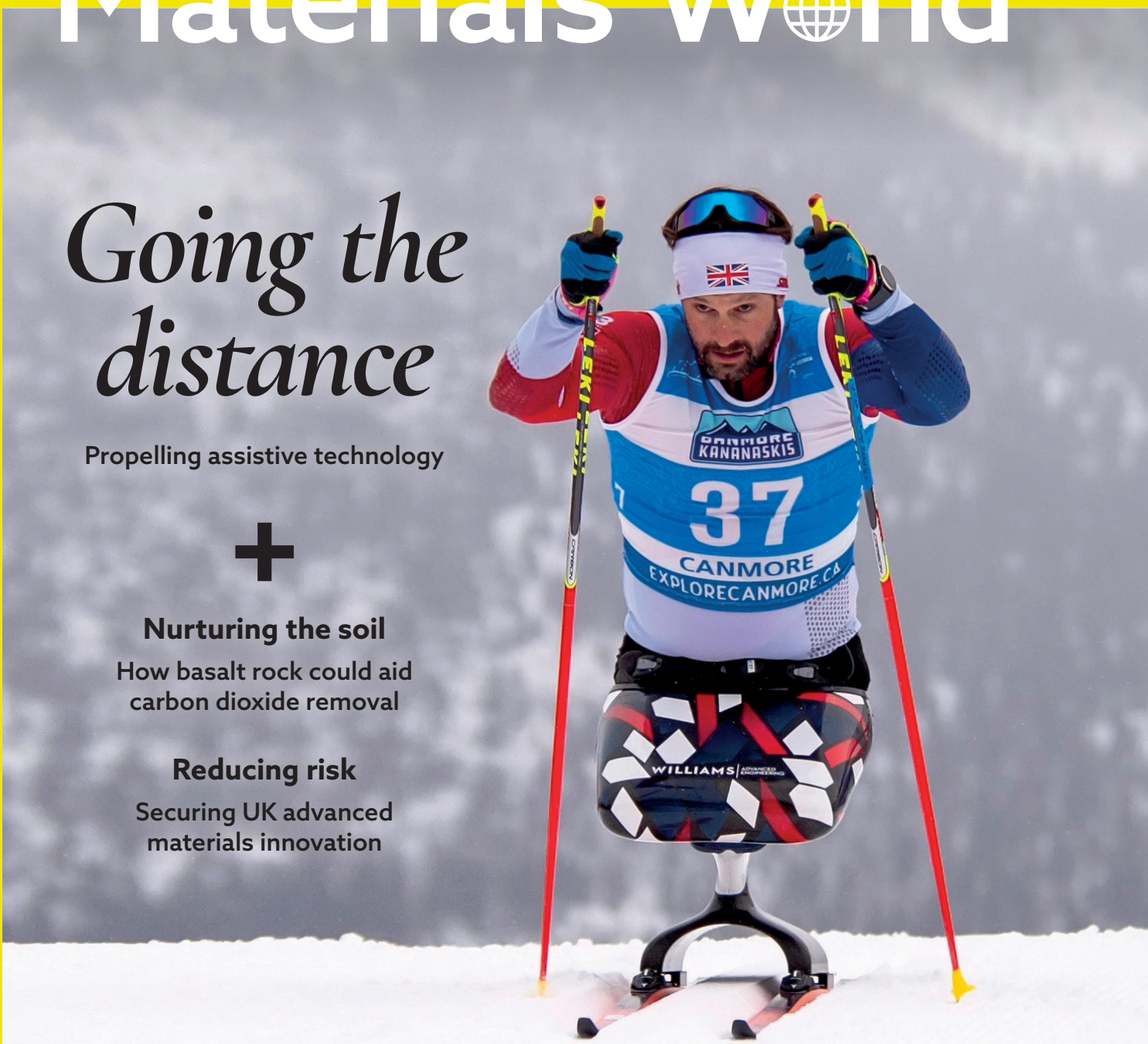
The member magazine of the Institute of Materials, Minerals & Mining

Volume 30, Number 6

Materials World



Going the distance

Propelling assistive technology

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Nurturing the soil

How basalt rock could aid carbon dioxide removal

Reducing risk

Securing UK advanced materials innovation

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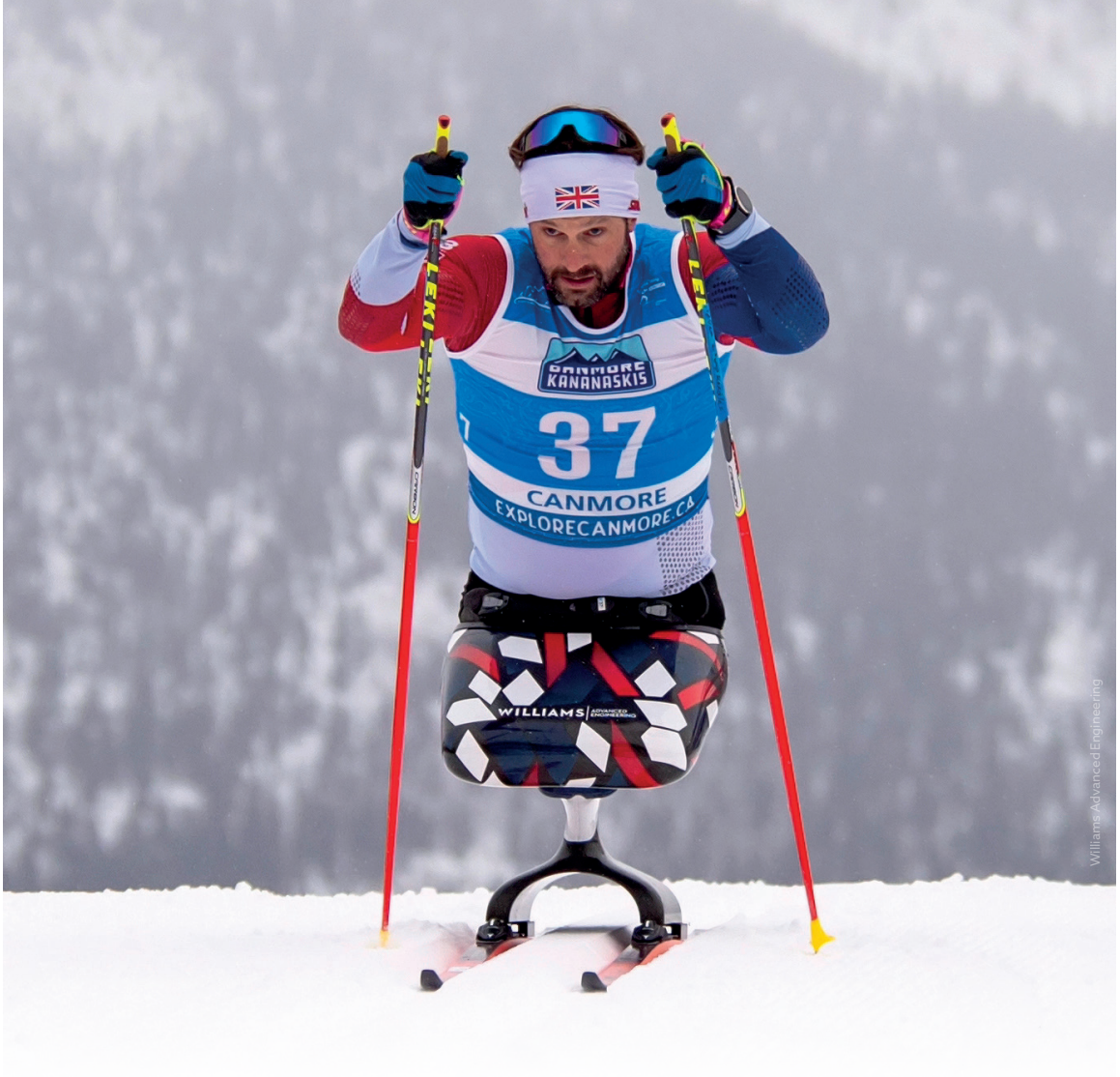


Williams Advanced Engineering

Going the distance

Assistive technology can have a transformative impact on people's everyday lives. *Andrea Gaini* looks at some of the advances that are propelling this field.

Above: The first competitive outing of Williams Advanced Engineering's Sitskis at a race in Canmore, Canada

Assistive technology (AT) is defined as any item, piece of equipment, software programme, or product system used to increase, maintain, or improve the functional capabilities of persons with disabilities.

This definition from the UK Assistive Technology Industry Association may include technologies that have an electronic component, but also more broadly, any tool that is intended to replace a lost function.

Paul Doyle, an Assistive Technology Consultant since the 1990s, explains that one of the key advances in AT is the development of new materials.

"Materials have certainly changed how assistive technologies have evolved over the years. If you think about some of the first prosthetic limbs, initially, they were made out of wood.

"And over the years, those limbs have been fashioned out of newer and more modern materials. In the Second World War, for example, a lot of prosthetic lower limbs were fashioned out of tin and metal because they were lightweight and easy to produce.

"More recently, limbs have become manufactured from high-tech alloys, lightweight alloys, and, even more recently, some of the more exotic materials, like carbon fibre."

For improved fit, Doyle notes that research is now focused on snug, tight-fitting sockets to reduce the chances of slippage. "The challenge for the materials community is to develop limbs that can work well with osseointegration. So, effectively driving the anchoring point into the residual bone."

Full throttle

Advanced materials, in particular, have paved the way for more robust, comfortable, and occasionally cheaper, AT products, claims Professor Andrew Parsons of the Department of Chemistry at the University of York, UK.

He points out that advances in nanotechnology and electrochemistry, for example, now allow metal to be woven into textiles, enabling electrical connectivity in the form of sensors or electronics to be embedded into a textile for health monitoring.

"Also, developing biomaterials that reside in a biological environment opens up possibilities for regenerative medicine, with applications including eye implants."

Parsons continues, "New materials have also found applications in prosthetics, orthotics and vision-related AT. Composite materials, such as glass- or carbon-fibre, allow for prosthetic and orthotic applications that are lightweight and can have a more dynamic response than traditional materials.

"This includes J-shaped running blades used by amputee athletes, which are made of strong and lightweight carbon fibre. Also, although racing wheelchairs are commonly made from aluminium, an increasing number incorporate carbon fibre, which can make the chair lighter and more stable."

He explains how highly flexible materials are also garnering interest for use in soft robots and exoskeletons, reducing actuation compared to more rigid exoskeleton suits. Exoskeletons, he says, are one of the most promising technologies in the field of AT.

"Modern exoskeletons are devices that assist an individual to perform movements. Some exoskeletons are designed to help individuals perform rehabilitation after trauma or injury with the goal of recovering full mobility," explains Tommaso Lenzi, a Mechanical Engineering Assistant Professor at the University of Utah, USA. "Other exoskeletons are designed to assist an individual's movements. These can help decrease an individual's effort or increase their performance."

Lenzi describes how "exoskeletons are typically realised using electro-mechanical actuators. Many devices incorporate high performance electric motors with custom mechanisms. These can be incorporated in rigid frames or into soft suits. A few devices use pneumatic actuators".

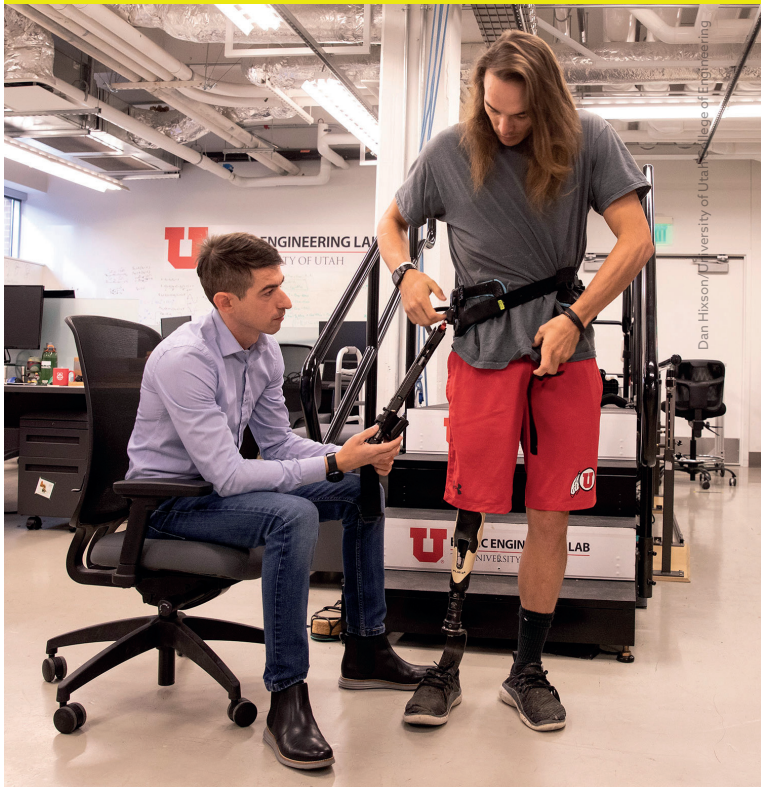
Experimenting with exoskeletons

Lenzi is part of a team that has developed an experimental exoskeleton made from aerospace-grade aluminium, steel and composite materials. The technology aims to allow users to walk with less effort thanks to a series of motors, microprocessors and advanced algorithms.

"Whether it is a rehabilitation device or an assistive device, the exoskeleton applies forces and torques to the user's limbs during movements. For example, some exoskeletons push or pull on the shank, thigh, or pelvis of an individual, supplementing the forces and torques generated by the user's muscles," he says.

The research team's brief was a device light enough that it was not a burden for someone to wear, yet provides high levels of assistive torque up to 40Nm.

Below: Tommaso Lenzi, of the University of Utah College of Engineering, USA, setting up the experimental exoskeleton designed for lower-limb amputees



The attachment points – the interfaces – that connect the exoskeleton to the user need to be stiff to transmit assistive forces and torques, yet comfortable and well-fitting so that the technology could be worn for long periods of time. The control algorithms need to adapt to different individuals, while still providing precise magnitude and timing of assistance.

To do so, the team has analysed gait biomechanics – the manner of walking – which reveals what forces are applied by the muscles to the limbs during movement. Then simulations predict the performance of an exoskeleton based on the gait biomechanics.

"The result of the simulations is a virtual exoskeleton design that has an optimal function. We then used this virtual exoskeleton concept to guide the actual design of the exoskeleton in which we select lightweight, high-performance components to develop a prototype," he continues.

To compensate for the amputee's overexertion of their residual-limb and intact-limb muscles, the exoskeleton provides assistive forces and torques to the thigh and pelvis while walking.

"Fundamentally it connects to the residual limb, above the amputation level, and rhythmically pushes and pulls the leg during gait, so that the muscles in the residual limb can relax. In other words, the exoskeleton helps the user swing their leg forward in the air and pull their upper body forward over their leg while it is contact with the ground," Lenzi says.

The microprocessors developed in this study read the sensors embedded in the exoskeleton to measure how the user moves

their legs during ambulation. Then, based on these movements, it determines the optimal action of the motors so that the exoskeleton can effectively assist the user's gait. For example, the exoskeleton pushes the trailing leg as it swings forward during walking. The microprocessor performs this 1,000 times a second so that the assistance is always in sync with the user.

The microprocessor also communicates via Wi-Fi to a tablet or computer so that a therapist can monitor how the exoskeleton functions and make changes as necessary for each user.

Lenzi adds, "The transmission mechanism is mainly made of anodised 7075 aluminium with shafts made from 440°C hardened stainless steel. This mechanism is housed in a carbon fibre frame and, with the electric motor, makes the actuation unit. The actuation unit is attached to the pelvis and thigh through composite 3D-printed components and textile wraps.

"We use electric batteries (lithium-polymer) to power the actuator and various embedded electronics to run the control routines, read sensor data, and transmit the data wirelessly to our control interfaces."

To prepare these materials for use in the exoskeleton, Lenzi says that the aluminium and steel components are machined using rapid prototyping services. Some smaller parts also require wire electrical discharge machining or broaching techniques to create certain geometries. The steel parts are hardened, bead blasted, or finished as appropriate while aluminium parts are anodised.

The exoskeleton uses a combination of artificial intelligence (AI) and machine learning combined with robot control techniques to synchronise the assistance provided by the exoskeleton with the user. "So, the AI is continually learning the motion of the user. The exoskeleton assistance is then provided based on the learned motion to help the user accomplish that movement," Lenzi shares.

He expects that AI and other forms of machine learning will be used to develop intuitive control systems that provide assistance as desired by the user. These systems could take advantage of a variety of sensors to gauge user intent by measuring electrical signals from muscles or nerves.

"AI and machine learning may also be used in the design process to help identify good candidate design."

Helping hand

Doyle foresees that 3D printing also has the potential to come into its own when used for AT, enabling highly personalised interfaces between the person and the prosthetic, as well as rapid production.

"I've worked with prosthetics and orthotics where the measurement of a residual limb, a stump, is done but then the process can be so long, that by the time the socket and the limb is delivered to the end-user, their physical stump has changed, has atrophied or grown, or the person has put weight on. And so, it can be quite a hit and miss process, interspersed with weeks and weeks of waiting. Whereas 3D printing can turn these things around in a matter of two or three days."

Parsons continues, "Malleable materials such as nylon or epoxy resin have been designed that can be deposited, layer-upon-layer, in 3D printing. This offers an effective, relatively inexpensive and customised production of components, leading to more personalised AT products from wheelchairs to hearing aids to gloves for wheelchair racers."

Hitting the slopes

3D printing was used for Team GB's equipment for the 2022 Paralympic Games in Beijing, China. The Sitskis, developed by Williams Advanced Engineering (WAE), has a main body of the fin and seat made from carbon fibre, while the interior and ski interface parts are made primarily of 3D-printed metals and plastics so that they can be complex, while still lightweight.

The skis were developed in a two-year programme. "We designed the concept in close collaboration with athletes, who provided feedback for every part of the journey, with a view to guaranteeing that the final product would be fully optimised for maximised performance," says Ollie Guild, Senior Product Designer at WAE.

Motorsport-derived techniques were a source of inspiration, including materials optimisation so that each part of the product is light yet durable and helps the athletes deliver energy straight into the snow.

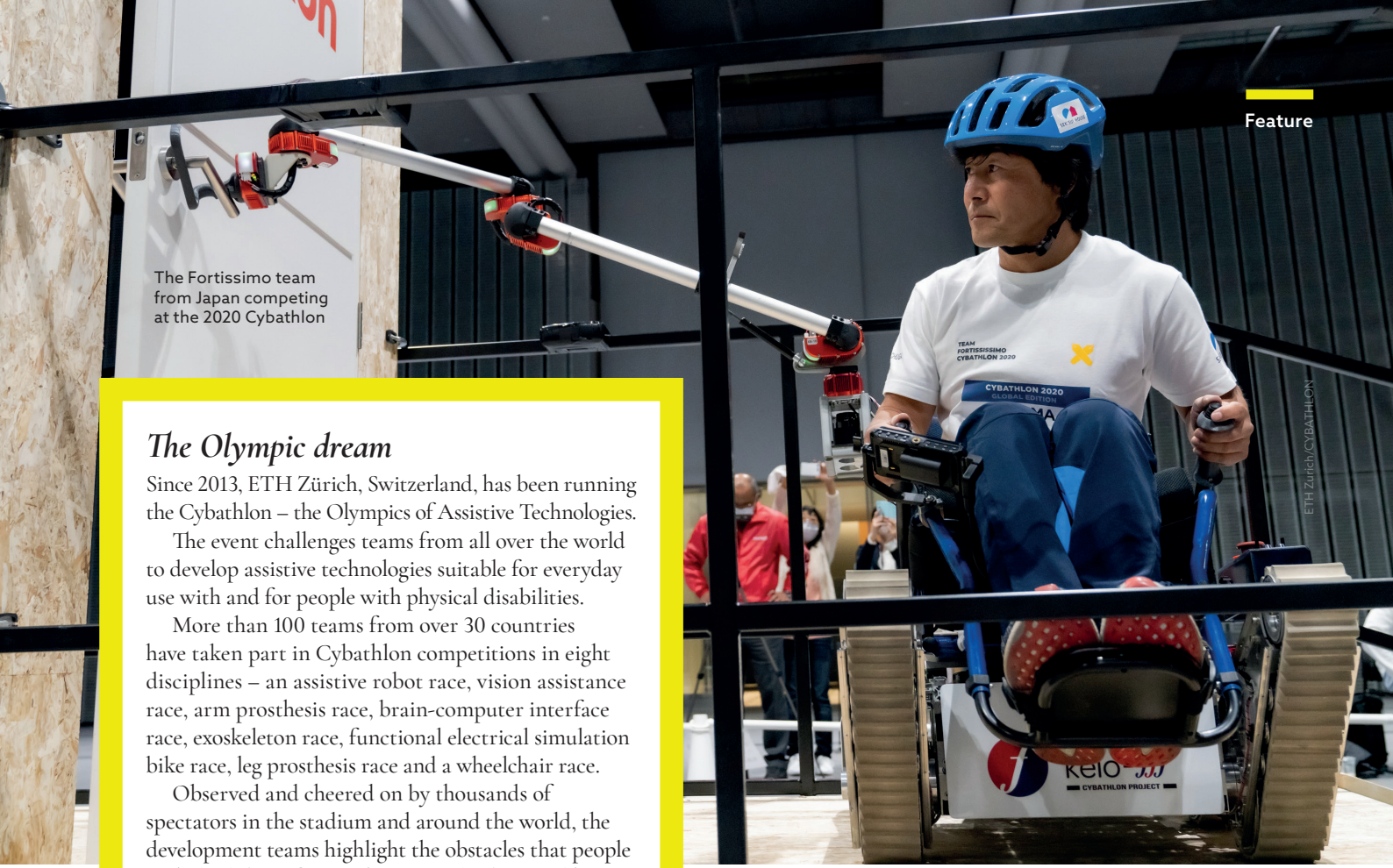
A prosthetic toe dating back to between 950 and 710BC, which is thought to be the first example of prosthesis

Did you know?

In 2012, the University of Manchester, UK, identified two wooden toes created by the Egyptians as possibly the world's first example of assistive technology.

The Greville Chester toe, now at the British Museum, dates back to before 600BC and was made of cartonnage, an ancient type of papier maché using a mixture of linen, animal glue and tinted plaster. The other discovery is the wood and leather Cairo toe, dating back to between 950 and 710BC, found on a female mummy near Luxor, Egypt.

The researchers propose that the toes could have been developed as a way for the user to wear traditional Egyptian sandals, which would otherwise be difficult due to the increased pressure that a missing toe would put under the foot.



The Fortissimo team from Japan competing at the 2020 Cybathlon

The Olympic dream

Since 2013, ETH Zürich, Switzerland, has been running the Cybathlon – the Olympics of Assistive Technologies.

The event challenges teams from all over the world to develop assistive technologies suitable for everyday use with and for people with physical disabilities.

More than 100 teams from over 30 countries have taken part in Cybathlon competitions in eight disciplines – an assistive robot race, vision assistance race, arm prosthesis race, brain-computer interface race, exoskeleton race, functional electrical simulation bike race, leg prosthesis race and a wheelchair race.

Observed and cheered on by thousands of spectators in the stadium and around the world, the development teams highlight the obstacles that people with disabilities face in their everyday lives and how technology can contribute to overcoming these barriers.

Teams consist of technology developers from universities, companies or NGOs, and a person with disabilities tackling various everyday tasks with the latest assistive technologies. The participants show how to tie shoelaces with a robotic arm prosthesis, balance on rocks with a prosthetic leg, or overcome uneven terrain with an exoskeleton.

The next games will take place from 25-27 October 2024.

"The seat and fin structures have material placed only where strength is required, to keep the overall weight down, as well as being strategically located to ensure responsiveness on the snow," shares Guild.

"Within each seat, the athlete has a moulded foam insert, inspired by the F1 driver seat fitting process, to make sure they are fully comfortable and 'at one' with their Sitski.

"We also worked on the aerodynamics of the 'fin' below the seat, to make sure the Sitski glided as effectively as possible to prevent athlete fatigue, especially at high speed."

WAE says they were in constant communication with the team during the construction, making sure the final product solved any concerns they had.

The Sitskis were tested through computer-aided engineering and digital materials testing, prior to validation of build at snow domes in the UK and Germany.

The location and positioning of the athlete in their seats above the skis are also key and so a number of different seat locations and angles were evaluated on balancing scales in the workshop. The rigs themselves were statically tested to understand their durability and wear throughout a race.

Throughout the summer season and during the pandemic when travel was restricted, the Sitskis were attached to 'mountain boards' used on roads in the UK to understand how the build, materials and athlete fit worked in real-life scenarios.

AT for everyday

Much like motorsport, where certain aspects of development are adapted for everyday cars and bikes, the work on assistive technologies for Paralympians is being taken into everyday products.

Guild explains that the Sitski has inspired the development of the DREAM wheelchair concept for young users.

WAE supported a review to provide recommendations on design, procurement and manufacturability to further aid the development of the wheelchair through its knowledge in the healthcare industry, developed through previous projects such as Babypod 2.0 and a Paralympic hand cycle, alongside its capability in product design and supply chain management.

He says, "The materials used ensure that weight and bulk is removed wherever possible and secondly [assure] the comfort of the user in regard to seating, which requires a high level of development and often custom additions."

Doyle sums up, "Without these particular assistive technologies, people are unable to work and able to make a living for themselves. They are unable to read, learn, all these things that we take for granted."

Also see Materials World, June 2021, for an article on a novel composite base for exoskeleton technology at bit.ly/3izU68A, and a webinar on The Future of Exoskeletons at https://bit.ly/3M56F7j

True grit

As the first woman engineer to become Global Senior Vice President at Jacobs, UK, *Catriona Schmolke FREng FIMMM* has spent her career breaking boundaries and persevering in the face of a hard "no". *Andrea Gaini* sits down for a chat to learn about the determination and tenacity that has shaped her career.

"When I was 16, my mother and I were called up to the headmaster's office. He sat us down and told my mum, 'I'm sorry to say that Catriona is not university material'", recalls Catriona Schmolke of the moment her hopes of going to university seemed to crumble in front of her eyes.

"My mum always had a strong authority towards the things she believed in, so she came out of that meeting and told me, 'Catriona, you are a smart, tenacious redhead, don't you ever let anyone tell you you can't do something.'"

Born and raised in Seamill, a small village on the west coast of Scotland, Catriona reflects on a "fabulous upbringing". Her mum worked at the Glasgow Tourist Board, while her dad was a Mechanical Engineer, a career he had entered after studying at night school and a good example of what perseverance can achieve.

Catriona now speaks with a strong sense of self and confidence, like her mum's words that day after meeting with the headteacher, but as we delve deeper into her story, she explains that she had to work hard to find her own way.

Buckling down

Despite her headmaster's discouragement and initially not getting the grades for some of the universities she had applied for, Catriona decided to look at other routes to get a place in higher education.

"My boyfriend at the time was studying at Strathclyde University so he suggested we go up to Glasgow and see if there were any clearing opportunities to get a place," she says. She recalls showing her grades to the "nice lady at reception" and being told she could either apply for a general science degree with a lot of maths – a subject she had grown to despise – or a degree in Applied Geology.

"I remember thinking, 'well, my brother is a geologist, how hard can it be?'," she says, chuckling to herself. She was offered a place that same afternoon after an impromptu interview with the course director, but the offer came with words of caution, "The director basically told me I would not pass the first year."

On her first day of class, Catriona had some trepidation when she saw that she was only one of two women in the whole class. "I never felt intimidated by all the men in my class, but I did have this feeling, what we now call imposter syndrome, believing I didn't deserve to belong."

> *"If you're good at your job, it doesn't do any harm to have a slightly different opinion or bring a new perspective to the table."*

Not one to let that dissuade her, the "tenacious redhead", as her mother called her, put in the hard graft and passed all her exams, graduating four years later with an Upper Second-Class Honours degree – a result that "many of those guys who had got into university with better grades than me did not achieve".

Catriona tells me she also holds an MPhil research degree in Mine Water Pollution from Newcastle University, UK. And in 2021, she was appointed Visiting Professor in Sustainability, Risk and Resilience. Quite an achievement for someone that was told they were not university material.

> *I developed a number of areas including a maternity mentoring network, as it was very important to create an inclusive workplace for our working mothers."*

Making connections

The experience at Strathclyde sowed the seeds of her career. While at university, Catriona was the student representative on the West of Scotland Geological Society, and later appointed Secretary, building a network of contacts that recognised her abilities and would play an important role in her career.

She got her first job as a Geologist at Johnson Poole & Bloomer (JPB), Scotland, UK, through a contact from the Society. At JPB "we focused on land that had been impacted by former mining and also the design of new opencast mines.

"I was there for three years, and I learnt a hell of a lot and understood a lot more about putting the theory of mining that I'd learned at university into practice."

After three years at JPB, Catriona moved onto an infrastructure consultancy, known at the time as Babtie Group (later incorporated into the engineering company, Jacobs) – once again through one of her contacts from the West of Scotland Geological Society.

"I was the first woman in the Geotechnical team, and I think that helped, because if you're good at your job, it doesn't do any harm to have a slightly different opinion or bring a new perspective to the table."

By 1992, she became a Chartered Engineer. "It was a really important milestone for me because I wanted to start a family. And in my head, I was worried that if I wasn't chartered, once I'd had a baby, I wouldn't be able to get a job again."

After having her first child a year later, she almost immediately had her second. She "started working part-time with one baby, and one on the way. And it was tough. I had five years where I had them under the age of five. But I had my mum and my dad at the time, and we worked through it.

"And interestingly enough, I grew in my career. I was promoted faster once I had two babies because I think I became super efficient, I became really focused and was soon made a Technical Director – the first female Technical Director at the company."

In her new role she was hiring and running the department and, by 1996, was in charge of a 200-person environmental consultancy within the Babtie Group.

"My environmental consultancy was almost 50% women, 50% men, and I had the opportunity to develop female leaders, as well as male leaders. This was possible because I worked hard to make the business unit as attractive to women as I could.

"Building on my own experience of maternity leave at work, I developed a number of areas including a maternity mentoring network, as it was very important to create an inclusive workplace for our working mothers, and around that time we began lobbying the company for enhanced maternity pay and also paternity leave.

"But I would look at other parallel businesses inside the same company who were still predominantly men. So, I definitely think female leadership attracts females."

Finding her feet

Fast-forward a decade and, in August 2004, the Babtie Group was sold to the American firm, Jacobs Engineering. Catriona recalls feeling shocked by this change, but also choosing to embrace it as an opportunity to expand her horizons.

Within the new company, she found a mentor in Marietta Hannigan, who worked in business development at the time.

She explains that Marietta was asked by the Jacobs leadership to move to Glasgow in 2005 to support the post-acquisition integration of the Babtie Group into Jacobs.

"Marietta, at that time, had been with Jacobs for around 14 years and had also joined through an acquisition. She is a dynamic and inspirational leader, and she was the first woman leader I had met who was senior to me.

"She taught me everything I knew about how Jacobs did business. More than 20 years into my career, I finally found my female role model.

"Marietta was able, through her experiences, to offer a window into the new company – which was 10 times the size of Babtie Group – and how it operated, and through her encouragement and coaching I moved role from an operations leader into a Global Sales leader," Catriona explains.

"Working alongside Marietta in Global Sales, I was part of a small group of leaders who went on to become the Global Sales Trainers of the company.

"We travelled internationally delivering sales training and this really helped me to broaden my horizons and understand how a multi-national, multi-billion dollar company operated.

"I also learnt how to further develop my operational leadership skills into corporate engagement skills, and as I became a Senior Vice President, that transition was essential to operate effectively at the C-Suite and use my influence with the Board and other key stakeholders."

Catriona on a safety tour inside the dome structure of the Capitol building in Washington DC, USA

A wind of change

Catriona also experienced, and was part of, a big transformation to the safety culture in the company.

The firm was shaken to its core in 2005 when an explosion at BP's Texas City refinery caused 180 injuries and 15 deaths, 11 of which were Jacobs' employees. After the incident, it set off on a journey to transform Jacobs' safety culture.

"We wanted our safety culture to be so strong, that you'd learn more [at work] so that you can go and be safer in your homes too.

"This was at the time a major shift in perspective and involved everyone in the company not just those working on sites. Everybody learnt that safety was their responsibility. It wasn't just about standards or specifications...but to normalise and tell people that if something doesn't look safe, then to have the courage to intervene and to feel fully supported in their decisions, we called it BeyondZero our Culture of Caring."

In 2016, in her role as Global Senior Vice President of Safety, Security and Sustainability, Catriona was able to formalise psychological safety within BeyondZero with the Mental Health Matters programme within Jacobs.

"There were people who wanted to do more about mental health at work, and I was honoured to be the ambassador to help them to bring forward a global mental health programme into the company.

"I pitched that to the Executive Leadership Team and with the energy and the talents of many people, we implemented the Mental Health Matters programme at Jacobs.

"The programme was completely voluntary, and people could come forward to be trained as Mental Health Champions.

"By the time I was leaving in 2020, there were nearly 2,000 Positive Mental Health Champions and the psychological safety culture had become the norm."

Catriona's work in changing the safety culture at Jacobs was recognised by the National Safety Council of America in 2021 when they awarded her with the Marion Martin Award, an honour given to influential women in safety.

Mentoring new blood

Catriona has recently retired from her position at Jacobs and is now building a portfolio career including Non-Executive roles on Boards and has her own consultancy. She also spends her time mentoring and speaking about leadership and women in engineering.

To the future leaders, Catriona says, "Humility, empathy, honesty and authenticity are the essential skills for the leaders of tomorrow.

"I think I have succeeded as a leader of people because I don't think I have all the answers. I know I need to rely on other people. I welcome their inputs. I can empathise with them."

She adds, "One of my mentors once said to me, 'You need to think about legacy. It is not about what you do today, but what are you leaving? It's about what do you want people to remember you for?'"

On becoming a Fellow of IOM3 in 2015, she was honoured as Fellow of the Royal Academy of Engineering (RAE) in 2016 for her work in mine water pollution and sustainability, becoming one of only five women in Scotland to achieve Fellowship of the Academy.

"As a new Fellow, I joined several committees and projects that the RAE was working on. It was a difficult juggling act with my full-time career at Jacobs, but I knew it was also important to use my voice and influence as one of only a handful of women Fellows," she explains.

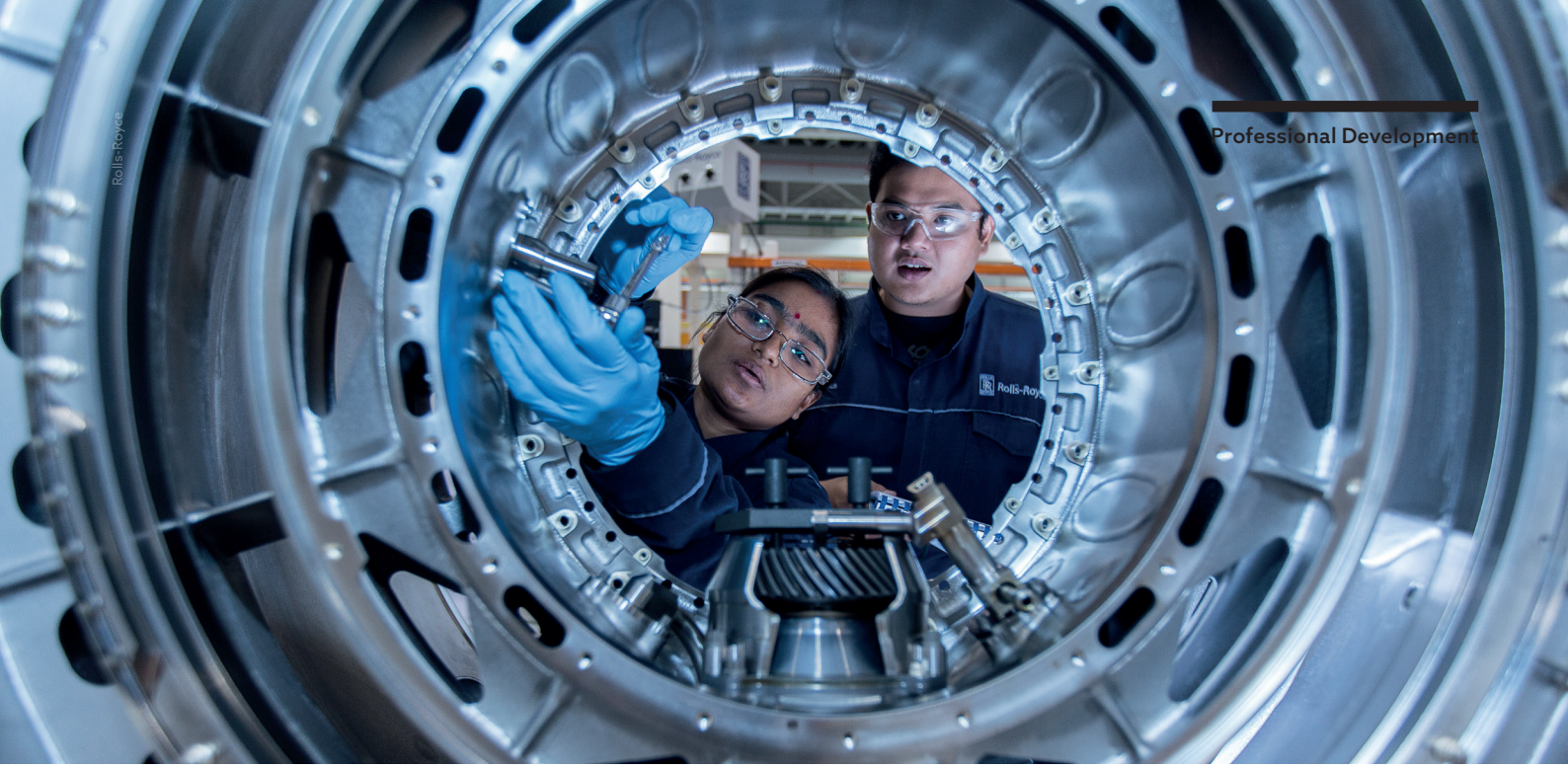
"In 2020, when I took early retirement, I was then able to devote more to the projects, such as the Engineering Leaders Scholarships (ELS) Steering Committee, which I chair."

The ELS is a scholarship programme for undergraduate engineers to financially support them in becoming an engineering leader of the future, she explains.

Catriona adds, "I was also appointed a Trustee on the Board of the RAE, in November 2021, and I was asked to extend my Trustee role to become the Vice President of Fellowship Engagement.

"I am one of two Vice Presidents who support the President and I am also there to support the RAE Executive Leadership team with engaging the Fellowship, to deliver their mission to harness the power of engineering to build a sustainable society and an inclusive economy that works for everyone."

To close, Catriona quotes Maya Angelou as one of her life mantras, "People will forget what you said, people will forget what you did, but people will never forget how you made them feel," and that in a nutshell is how she has moulded her leadership strategy.



Making inroads

Unlocking success when it comes to diversity and inclusion was the aim of the UK Royal Academy of Engineering's annual conference on the topic. *Andrea Gaini* went along to find out more.

"If the last two years have taught us anything, it's the enormous capacity of engineers to rapidly mobilise and innovate to the profound benefit of society," explained Professor Sarah Hainsworth FREng FIMMM, Chair of the Royal Academy of Engineering's (RAE) Diversity and Inclusion Committee, kicking off the organisation's event on 'What Works in Diversity and Inclusion?'

"Taking inspiration from the incredible work of the world's engineers in response to the pandemic, we want to focus on [this] collective capability to make a dent in a crisis that [is creating] barriers to diversity and inclusion (D&I) in engineering.

"We know that as an industry, we still have a long way to go before we can say with confidence that we are diverse and inclusive, and have a culture in which everyone feels they belong."

Hainsworth reported on the RAE's latest statistics revealing that just 16.5% of engineers are women and that people with disabilities are under-represented in the field – only 11.1% of those in engineering occupations identify as disabled, compared to 14.8% of those in non-engineering occupations.

"Those from minority ethnic backgrounds are also under-represented, holding just 10% of engineering occupations compared to 13% of the UK workforce," she added.

Hainsworth noted that the last time the Academy surveyed engineers about inclusion in the industry, they discovered a mixed picture. "For example, women engineers are less likely to speak up on inappropriate behaviour than their male colleagues, and black, asian and other minority ethnic engineers are less likely to think that promotion processes are fair – so we have a collective responsibility to contribute to creating a more equal engineering profession."

According to Hainsworth, 80% of engineers say they feel more motivated when they feel included, and half reported that this increases their commitment to their organisation.

"Research and experience show that the best products, systems and processes come from diverse teams working in inclusive cultures. So, the importance of increasing diversity and inclusion cannot be overstated."

For good measure

To make this transformation, curiosity, creativity and a constant drive for knowledge will be crucial. Understanding how to monitor and measure success will also play an important role, added Hainsworth.

Louise Parry, Director of People & Organisational Development at Energy & Utility Skills, UK, joined the conversation on setting targets to measure success in D&I.

Parry has been involved in research that looks at the lack of women on corporate boards, and was invited onto Lord Davies' independent review of the lack of women in leadership positions. She also sat on the Hampton-Alexander review, successor of the Davies review, which concluded in 2021.

She said, "The voluntary targets [for women in leadership positions], set by both Davis, Hampton-Alexander and now by the Parker reviews, are very much being reinforced by the Financial Reporting Council...there has been a real push to require much richer D&I reporting, which I value, because I think there is something to the phrase, 'what gets measured does get done'."

Parry also analysed the downside of voluntary targets, "Eleven years on, we are noticing a variance across companies. With quotas, you actually mandate that every company meets that particular quota. Whereas with voluntary targets, it does lead to variance. That being so, I don't want to downplay the importance of targets, I think targets have now caught on and become really embedded in organisational life, through the influence of FTSE 350."

Parry highlighted the importance of spreading targets at every level of an organisation. "Every manager, every director, needs to be challenged as to why the number of people being promoted at each level does not reflect the percentage in the talent pool at that level."

As the sector strives to measure success in D&I equally and fairly, Dr Uracha Chatrakul Na Ayudhya, Assistant Dean for Equalities and Diversity at Birkbeck University of London, UK, added that having these benchmarks and macro-level indicators of D&I in organisations helps to see how progress is being made, at what pace, but also where the problems still lie.

She cautioned, however, that these benchmarks need to be aligned with protected characteristics of equality – including gender, race, ethnicity, disability and sexuality.

She advised, "Think about to what extent do these macro-level indicators speak to the micro-level interventions in the organisation."

She postulated that when thinking about what success looks like for an individual, we think about the extent to which this is innate, or something that has been developed and nurtured through socialisation and exposure.

"We recognise that some of these measures, such as psychometric testing, cognitive ability testing, personality testing, interviews, panel interviews and other forms of selection and assessment...have been historically designed to exclude people rather than to include them."

She invited attendees to reflect on the practices that enable people to progress and to show their true potential without measuring individual level characteristics that have not actually been nurtured in the organisation.

> *"Every manager, every director, needs to be challenged as to why the number of people being promoted at each level does not reflect the percentage in the talent pool at that level."*

Above: This is Engineering is a campaign by the Royal Academy of Engineering to encourage more people to pursue engineering. A library of images seeks to represent the broad and diverse talent pool of engineers

She continued, "When we talk about macro-level benchmark data, indicators of D&I, to what extent are organisations able to capture this data in a way that allows for intersectional analyses? It is not enough just to look at these characteristics in silos, we know that there are intersections of different social identities, categories and forms of oppression in society.

"So how do they interact? And how do they actually shape the lived experience of the very people that you would like to nurture and the talent that you would like to bring out through the organisation?"

Invisible characteristics

Chatrakul Na Ayudhya also pointed to the difficulty in measuring hidden characteristics, such as invisible disabilities, and how we normalise the conversation without stigmatising.

She asked, "Why are some people reluctant to self-report certain protected characteristics? Is it potentially because they feel that it is not a safe space? And will it actually be a barrier to their career progression?

"And this links in with the idea of, in organisational psychology and organisational studies, [there is] the concept of the ideal worker and who falls out of that. If you are up for promotion progression, what is the image of the ideal worker?"

One of her research areas focuses on the fertility journey in the workplace. "Just by indicating to employers that you are thinking of having a family, and somehow you are having difficulties with your fertility journey and that you might need time to get treatment, that in itself could be seen as a form of career suicide, particularly in sectors where the ideal worker is upheld as someone who is unencumbered by any other responsibilities except for work."

Welcome mat

The event also explored the ways in which organisations can create a welcoming environment for their workforce, and the benefits that this may provide.

Pavneet Khurana, Head of Inclusion & Projects at Unleashed, UK, highlighted how D&I means different things to different people and organisations, and that an individualised approach might be required in certain scenarios.

She said, "If we think about the broad definition of inclusion, it is the act of creating an environment that values, supports and accepts every person.

"Part of the work on how to create an inclusive culture is to help people to take that step away from avoidance and away from fear, and to bring them into a space of action."

Unleashed has created a framework of five 'levers of change' to help organisations answer 'what does an inclusive culture really mean to us?'

Data for exploration, instead of measurement, was identified as the first lever to success. "Understanding how we can widen our vision through data, asking questions to our teams, to the individuals within our organisation, asking them about their lived experiences, to contextualise some of the ambiguity that we might be experiencing," Khurana said. This can be achieved quantitatively gathered through surveys, conversations and workshops, as well as discussions.

"Accountability for inclusion sits across everybody within the organisation, but it starts at a leadership level," she said, presenting leadership as the second lever for change.

"Are they role modelling inclusive behaviours? Are we gathering feedback from other people within the organisation about what they think and how effective they think the leaders are with this work? And actually, are leaders, as individuals, widening their vision as well, how are they educating themselves?"

Crafting or reassessing a company's current D&I strategy is also said to be beneficial. "Looking at our current organisational goals... through the lens of D&I. So, our product strategy, our marketing strategy, our growth strategy, if we were to look at those through the lens of inclusion, we will see something completely different."

Culture and people's experiences are the final pieces of the puzzle. Khurana continued, "A prominent part of this is to explore how we are defining our culture. Do we understand what a unique organisation with the principles of an inclusive culture looks and feels like? Are we crafting an experience through our culture that honours those principles?"

The different facets of the employee experience, like performance evaluation, can also be looked at through the lens of inclusion and equity.

"Even asking questions around, why are people leaving? How are people experiencing the performance conversations? Are there fair opportunities for learning and growth across all people in the organisation? And that's without looking at that through a demographic lens, but through...hearing individual voices."

A personal journey

Greg Turner-Smart, Diversity and Inclusion Lead at Rolls-Royce, UK, shared his own personal journey of coming out as a gay man, and how feeling accepted and supported in the workplace changed his career progression.

"When I first started working, during that entire phase of my life, something just was not right. I was not particularly happy. I was always on the fringes of whatever was going on, not really in the centre of anything. And performance wise, maybe wasn't living up to expectations or performing as I wanted to.

"To me, there was no mystery about it. It was clear what was causing me to be like that – something that I had known since I was 12...that I happen to be a gay man."

Turner-Smart explained that being brought up in the Northeast in a mining community, being in the 'closet' at that time felt essential and hiding that part of his life became the norm. That affected the way he behaved and interacted during his studies and early career.

"Fast forward to 2006 when I joined Rolls-Royce. At that point, I would describe my mental health as being fragile.

"So, I started to reconsider the way I was behaving, and I decided from that point onwards, no more lies. I would be honest if somebody asked me a question and...coming out became a mechanism through which I started to introduce myself to people, the real me."

In 2015, Rolls-Royce decided to launch an LGBTQ+ employee network and Turner-Smart was asked to lead the group.

He accepted and "that meant I became instantly visible. The very first event we did, we had 200 people in a room, I stood on the stage and introduced myself, 'Hi, I'm Greg, and I'm a gay engineer.'

"That second, as those words came out of my mouth, I could feel the pressure come off my shoulders – instantly, it happened."

The visibility gave him a community of people who knew about his journey and had had similar challenges.

"And, in turn, we then could create a support network...And perhaps, most importantly, it gave that community a voice.

"So, what is the impact of that? For me, personally, instantly happier and healthier...and my performance improved dramatically at work, [and] pretty quickly I received back-to-back promotions."

Also listen to a new IOM3 Investigates podcast on Building a Successful LGBTQ+ Network Group at bit.ly/IOM3Investigates

Did you know?

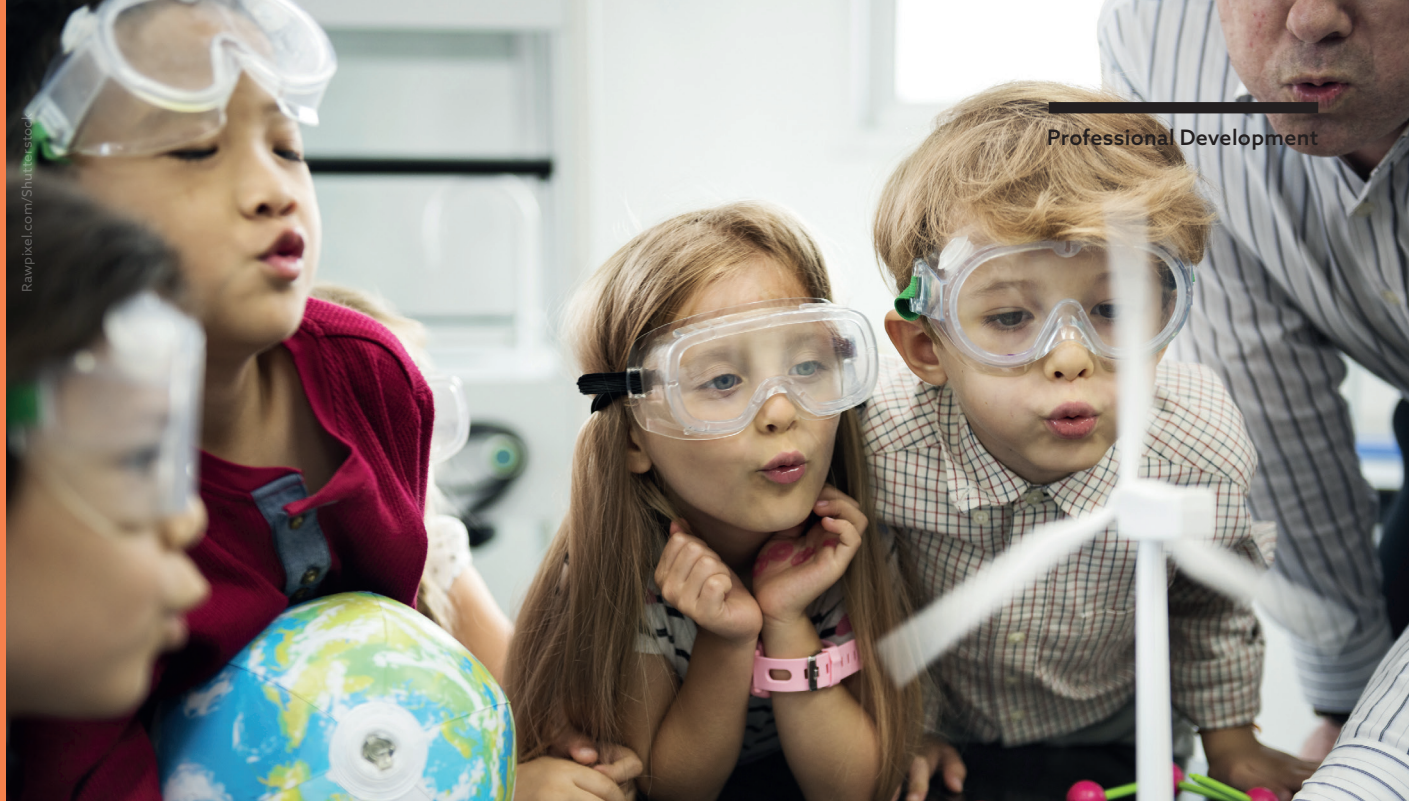
In 2021, women-led Starling Bank launched the campaign 'Make Money Equal' to change the representation of women in finance.

The move was motivated by a study of 600 images relating to men and women in finance put together at Brunel University. Starling Bank reveals that women are often represented as 'childlike' with their money, pictured with pennies and piggy banks, compared to men who are usually photographed with notes.

The researchers believe that this representation carries genuine consequences, not only negatively impacting how women are treated when it comes to finance, but also how they feel about themselves and their capabilities with money.

To tackle this issue, Starling Bank has teamed up with Lensi Photography to create a new image library of 100 photographs that better represents women and money.

Anne Boden, founder and CEO of Starling Bank, says, "Financial inequality doesn't end with the wage gap – it's all around us in the images we consume, often subconsciously, every day. That needs to change."



Reinventing science education

An event hosted by the UK Westminster Forum honed in on the priorities for science education in preparing tomorrow's leaders to face the big societal challenges ahead. *Andrea Gaini* reports.

"There is no doubt that we live in a rapidly changing world. New technology is developing, maturing and changing the way we work, the way we rest, the way we play and interact with each other," said Stephen Metcalfe MP, Chair of the UK Parliamentary and Scientific Committee, in his opening remarks for a conference dedicated to the next steps for science education.

"Technologies such as artificial intelligence and automation are becoming commonplace in our day-to-day lives, Big Data and data science are underpinning many of the developments that we're making, and quantum computing and sensing are beginning to take hold.

"We also face a huge number of challenges both nationally and globally, from addressing the issue of climate change and decarbonising our economy, to feeding an ever-growing world population, ensuring they have clean water and sanitation and access to healthcare.

"I believe we can rise to those challenges. Indeed, I think we can embrace them and turn them into opportunities. But to do that, we need to equip our young people…with the skills to be able to do that, to solve problems [and] ensure that they, and the UK, can prosper in a globally competitive world."

Sparking an interest

In a recent Oxford University Press (OUP) survey, *The Evolution of Science Education*, of the nearly 400 teachers that responded, only 30% believe that current science education is fit for the future.

Amie Hewish, Head of Secondary (STEM Subjects) at OUP, reported on the *Programme for International Student Assessment (PISA) Science Framework development for 2025*, a framework to inform discussions about the future direction of the PISA Science test. She reflected, "The strategic visioning exercise that we took part in proposes that a future vision of science education should include a dimension on scientific identity. And when we're talking about scientific identity, we're talking about how a student identifies with Science".

She explained, "The pandemic has reduced experiences…it's reduced [students'] exposure to…Science teachers, who in some cases have played a really key role in how they see themselves as Scientists, and how they can identify with a future path in Science."

Hewish talked about the importance of disciplinary and practical science, as well as the coherence between disciplines and with other subjects.

"Each scientific discipline has its own story – it has its own power, and it has its own fundamental concepts. And studying in a disciplinary way really helps students to develop their understanding of the science of the sciences.

"But it's in those boundaries where the sciences overlap, and actually where the sciences draw on enabling competencies, such as working with data and computing and mathematics, that there's a real awe and wonder and where a spark can be ignited. An example would be something like genomics and informatics."

Dr Michelle Saunders, Science Curriculum Lead at St Matthew's Catholic Primary School in Prudhoe, UK, contributed to this discussion drawing on the challenges of teaching.

She said, "Not only are you teaching Science, but you are also teaching English, Maths, History and a whole range of other subjects. Trying to…allocate sufficient time in the curriculum for Science can be quite a challenge, and particularly in the last year or so when we have knock on-effects of home learning."

However, she explained that this is a crucial time to be teaching Science as research shows students have often already made up their mind about whether there is a career for them by the age of 11.

"Most primary teachers are not Science trained, they will rarely even have A-level Science, never mind beyond that. And that causes quite a significant lack of confidence quite a lot of the time, however enthusiastic you might be, particularly when it comes to sciences like Physics, as they can be quite challenging to teach.

"One of the key areas of work that I think needs to be done to support primary teachers is to increase their subject knowledge, [because] teacher confidence is really going to impact how well a subject is taught and how well a child can understand and engage with Science."

She also argued that developing a high-quality curriculum will play an important role in sparking an interest.

"We need to look particularly at Science to ensure that we have a progressive curriculum, right from early years... and into secondary school. And quite often that barrier from primary to secondary proves to be the sticking point."

Dr Lynne Bianchi, Director of the Science and Engineering Education Research and Innovation Hub at the University of Manchester, UK, revealed the key findings of its report, *The 10 Key Issues with Children's Learning in Primary Science in England* (see box-out below). They found that "children experiencing fun Science activities fail to deepen or develop new learning. We want children to enjoy Science, but we want them to enjoy Science in the most purposeful and meaningful way.

"If our time is limited within the curriculum, we must make sure that every moment is a moment where a child makes progress and deepens their understanding of concepts and strengthens their skills...[Another issue is that] children are currently not necessarily drawing on their prior scientific skills".

As it stands, in primary school at least, science is often seen as one big subject without identifying the different pathways.

"We should separate the scientific disciplines of Biology, Chemistry and Physics, in the way that their curricula describe, the way that they are timetabled, and most importantly, the way in which teachers are recruited and deployed to teach each of them," explained Charles Tracy, Head of Education at the Institute of Physics, UK. "Re-establishing an expectation that each of the sciences has its own identity within the curriculum and is taught by an infield or specialist teacher.

"We did a survey of timetables a couple of years ago, and [we found that] nearly half of schools do not distinguish the disciplines on the timetable. They don't prioritise teachers teaching in their home discipline and, in over a third of schools, the three sciences are shared between two teachers.

"These restrictions are usually expedient rather than philosophical. They're based on technicalities of timetabling and teacher availability rather than what is best for the student."

Advancing accessibility

Clare Harvey, Chief Executive at The Ogden Trust, which collaborated on the above-mentioned report with Manchester University, affirmed the vital role of careers education.

She said, "Careers education is a really important way to tackle this because it enables them to meet Scientists, to see who Scientists are, what kind of people they are, and find ways that they can identify with someone in that scientific role.

"The Aspires 2 report [by the Association for Science and Discovery Centres] found that working class, minority ethnic students and girls were significantly less likely to receive and benefit from high-quality career support."

The report found that middle-class students identifying as male, or students with high levels of 'family science capital', were much more likely to aspire to a career in Science and want to feel, and be recognised by others as being, 'science-y'

"So, it's really important that we do all we can to support the schools and employers to be able to access all of those young people who might not have the social networks between them and their family and friends to have met Scientists or come across them in their daily life," asserts Harvey.

Helena Dodd, Research Postgraduate in the Department of Chemistry and Chair of WOMENinSTEM at Imperial College London, UK, drew on her personal experience.

"I myself am an example of someone from a working-class background who had never met a Scientist before, and had no family members that had been to university. So, I am aware of the

Unlocking science learning

A report from the University of Manchester and the Ogden Trust, UK, released last year, outlines the 10 key issues with children's learning in primary Science in England. They are reported as:

1. Children's Science learning is superficial and lacks depth.
2. Children's preconceptions are not adequately valued.
3. Children's Science learning lacks challenge.
4. Children are over-reliant on teacher talk and direction, they lack autonomy and independence in learning Science.
5. Children experience 'fun' activities that fail to deepen or develop new learning.
6. Children are not encouraged to use their own curiosity, scientific interests and questions in their learning.
7. Children are engaged in prescriptive practical work that lacks purpose.
8. Children do not draw on their learning from prior scientific skills, they do not build on repeated and regular experiences.
9. Children rarely see themselves, their families, community members or their teachers as Scientists.
10. Children do not apply literacy and numeracy skills in Science at the standard they use in English and Mathematics.

Only 30%* of teachers believe that science education is fit for the future.

Source: *The Evolution of Science Education* survey, Oxford University Press
*Survey of approximately 400 teachers

struggles that people from maybe less represented backgrounds face, and how it just is that much bit harder to get into a Russell Group University, do well and go through a research career.

"For me, when I was young, and I was in school...doing well in Science, all my teachers told me, 'You should go into medicine when you're older'. I think there was a lack of awareness of STEM careers beyond medical and caring careers.

"So, it was only when I was 17, after I'd been pushed into medicine for quite a few years that I realised that medicine wasn't for me.

"There were other things that were a better fit for me, and I settled on Chemistry. So, I think it's really key to encourage careers in Science that are broad, and I think particularly Engineering – there's been quite a lack of understanding of what Engineering is and showcasing that to young people."

She continued, "I think academics can be quite notoriously within their own bubble, and can be quite bad at communicating with people that aren't in academia. So, I think it's very important to have more academics involved in showcasing their work, showcasing what university is like to make this a less intimidating environment to people that have no experience of university and may have never had a family member who has been there."

She explained that one of the ways she tries to tackle this is to bring role models into schools.

"And I think it's important to have various career stages represented because it's all well and good to bring in a really senior professor – they're very inspirational, but I think they're not really relatable... young people might think, 'this is 20 stages ahead of me, I can't see where the other 19 are.'

"So balance is very important, and I think it's also important to showcase people from different backgrounds, because within a single classroom, there's so much diversity, and all the children there will have different experiences."

Tackling teacher attrition

Tracey continued, "And if we look at the up-take [of] Physics across socio-economic quintiles, you're three times more likely to take Physics A-levels if your family is in the highest socio-economic quintile than in the lowest.

"It should be an entitlement that all students in all schools from all backgrounds have access to infield Physics...Biology and Chemistry [teaching].

"Not only are we short of Physics teachers, there is still a net loss every year, and that's partly due to teacher attrition. About 43% of Science teachers have left within five years of qualifying.

"One aspect is the burden that we put on these teachers, particularly in their early career, that burden being much greater than teachers of other single subjects. It arises from expecting these teachers to teach three disciplines rather than one, usually up to GCSE.

"And where this requirement used to be the exception 20 or 30 years ago, it has now become the norm. And it's tough...they have three times as much preparation to do.

"It's less rewarding because they're teaching outside subjects that they chose, and they will feel less effective themselves. And with fewer repeat lessons, they take longer to get really good."

Leading by example

Jo Pennington-Wright, Head of Science at Tring School, Hertfordshire, UK, spoke about the journey her school has been on for the last nine years.

"[Our] aim was to make [students] more resilient, when it came to examination, and empowering them in their own learning, and establishing the curiosity that we wanted in the classroom.

In 2014, they redesigned their Key Stage Three and Five curricula to be more activity, rather than instructive, based, where the students help to lead the learning.

"So, the first term in Year Seven, we don't do any content at all, we focus on investigation skills. And we've also put in some case lessons, which I think are really important for those thinking skills, at Key Stage Three."

She noted that the biggest challenge was the leap of faith to give up control and put the learning back onto the students.

"In 2016, we became a Google school and every student now has a Chromebook. And it has actually revolutionised the way that we share resources with others and the students. And we've designed our own websites – we are able to give back direct feedback, we can do collaborative work together, students have access to online textbooks, online revision resources – everything that's chosen by us, we know it's appropriate for them.

"During lockdown, we had to go fully electronic, but we have bought this back into the classroom. And actually, it's really helped students [and] it also helps us centre students, because they can work at different paces and without it being highlighted within the classroom setting."

Metcalfe summed up the event talking about the need to "reconnect businesses with our education system to ensure that their aims are aligned, we need greater cooperation across the whole education system, so that the hard barriers between the various changes in education are smoothed out.

"We need to help individuals, the students, the parents, the influencers, understand the exciting opportunities that exist [in Science] outside of the classroom."

Also listen to IOM3 Investigates...Materials Science Outreach for a podcast on encouraging more people and those from different backgrounds into Materials Science at bit.ly/36RicrW