Scientia

PIONEERING APPROACHES TO INCLUSIVE EDUCATION

EXCLUSIVES:

- National Science Teachers Association
- STEM Education Coalition
- National Institute of General Medical Sciences
- The European Federation of Geologists

HIGHLIGHTS:

- Supporting Children with Challenging Behaviours
- Making Researchers of STEM Undergraduates
- Investigating Disparities in Higher Education Environments
- Harnessing Mobile Technology to Improve Student Retention

Issue: #119

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WELCOME...

This special issue of Scientia focuses on enhancing education, ranging from early childhood schooling to postgraduate training and beyond, with a particular emphasis on STEM subjects. We explore an impressive range of initiatives aiming to promote uptake, retainment and achievement in STEM.

In the first section of the edition, we look at the important work of researchers who recognise the necessity of introducing children to science at a young age. Here, we read how stimulating exposure early in education helps promote the development of our next generation of budding scientists. We also introduce innovative approaches to overcome obstacles to educational attainment, such behavioural and emotional difficulties.

In the second section, we consider the impact of practical, hands-on experience in scientific research at undergraduate level. We also consider the importance of supporting students at this level from underrepresented backgrounds, such as women and those from minority groups. This leads us to our third section, which specifically considers the need for diversity in science. In keeping with the previous sections, we discuss several pioneering approaches across educational and training provision with the aim of widening opportunity and promoting achievement in science across the broad spectrum of society.

In the final section, we take a closer look at the importance of innovation in supporting teaching and education. Here, we read of further interventions aiming to increase student engagement, retention and academic success – and also the benefits on a personal level, including the nurturance of critical thinking, problem solving, and creativity.

Through embracing pedagogical innovation, the initiatives featured in this edition represent the breadth and depth of current efforts to diversify and expand upon our future workforce, for the benefit of all.

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Meet The Team...

CONTENTS

ISSUE : #119

SCHOOL CHILDREN

UNDERGRADUATE RESEARCH

DIVERSITY

INNOVATIVE TEACHING

SCHOOL CHILDREN

ENGAGING SCHOOL CHILDREN IN STEM EDUCATION

In the first section of this edition we introduce researchers and educators who bring science and engineering alive in the classroom to inspire children to become the next generation of researchers. As the world faces an increasing demand for professionals in the fields of science, technology, engineering and mathematics (STEM), it is more important than ever that children are engaged with these subjects from an early age.

To open the section, we feature an exclusive interview with Dr David Evans, Executive Director of the National Science Teachers Association (NSTA), the world's largest professional organisation for science educators. He talks to us about the challenges facing STEM education, and how to address the low levels of scientific understanding and literacy in the general public. He also tells us about how the NSTA is working to educate young people, so that they can join future debates on important issues such as climate change, with a greater understanding of the key scientific principles involved.

The next few articles in this section will focus on initiatives that promote better learning in the classroom, with a particular focus on STEM subjects. Of course, improving learning in the classroom requires that teachers are equipped to teach challenging concepts, and support their teaching with engaging practical activities. This very much describes the work of Dr Mary Ann Jacobs and Dr Zahra Shahbazi from Manhattan College, who we'll meet in the first article of this section. The initiative they have developed, known as 'Engineering STAR', is designed to facilitate collaboration between teachers and engineering professors to improve engineering education in their classrooms.

The DITLE project is another example of an initiative that aims to enhance learning in the classroom. DITLE was formulated by an interdisciplinary team from the University of Cincinnati School of Information Technology and the School of Education. Their goal, by way of authentic and hands-on learning experiences, is to increase high school students' engagement in IT related topics, thus broadening their prospects for the future.

Next, we meet Dr Jesse Heines, Dr Daniel Walzer and their colleagues at the University of Massachusetts Lowell, who are experts in both computer science and music. With this unique combination of skills, they are developing programs that spark students' interest in information technology. The team's innovative educational approaches not only allow children to learn computer programming skills, but also help them foster an interest in music.

We also meet the Ocean Tracks team, who bring the world's oceans into the classroom to give school children hands-on experience with environmental data. This interdisciplinary team of marine biologists, educators and web designers has created a web interface that offers students and school teachers access to a massive amount of real data on marine conditions and animal migrations. One of the great challenges for the future of science will be analysing and interpreting the ever-increasing amounts of data collected on complex systems such as Earth's climate. Therefore, the Ocean Tracks project helps young people get to grips with working with big data, while also introducing them to the world of environmental biology.

Next, we're going to take a step back and examine some of the issues surrounding STEM education in schools, such as policy and community involvement. Here, you will read an enlightening interview with Lindsey Gardner, Director of External Relations for the STEM Education Coalition. She explains how the STEM Education Coalition is investing much time and energy into expanding the

capacity and diversity of the STEM pipeline, advocating for policy and legislative improvements, and getting funding to where it's needed most.

Another important issue is that for some children, education can be challenging. Disruption to education at an early stage can have long-term impacts on a child's education throughout their school years, negatively affecting their future quality of life. In the latter half of this section, we feature the work of educational researchers who are finding new ways to help teachers engage and work with children who display problematic behaviours in school.

In our first article on this topic, we meet Dr Andy Frey at the University of Louisville. His team has been developing intervention programs to work with teachers and parents to help children with behavioural problems to reach their full potential. These programs not only help children to improve their educational experience and career prospects, but can also have a positive impact on their health and wellbeing later in life.

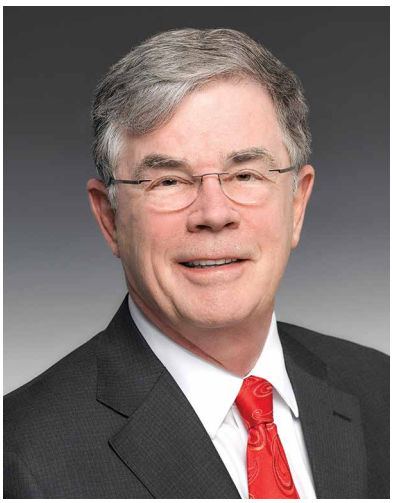
Dr Maureen Conroy at the University of Florida and Dr Kevin Sutherland at Virginia Commonwealth University have also been developing a program aimed at improving how teachers and children with chronic behavioural problems interact. By working to support teachers in how they interact with children, the program aims to tackle behavioural problems at an early stage – when interventions are most effective. Targeted interventions of this kind can help children who are at risk of developing emotional and behavioural disorders, potentially preventing further mental health problems in adolescence and adulthood.

Taking a closer look at the impact of early problems in school and the long-term impact this has on future education and health, Drs Jan N. Hughes and Stephen G. West of Texas A&M University and Arizona State University completed a 14-year study investigating the effects of repeating a year, early in a child's education. Long-term in-depth studies of this kind are rare, but provide the best evidence for how different educational practices early in school can impact on the chances of completing high school. This work is of vital importance for understanding and improving dropout rates and enhancing the future lives of the children affected. Dr Hughes, Dr West and their colleagues have made their comprehensive and unique data set available to other researchers, in the hope that as much as possible can be learned from this landmark study.

The future of all our lives can only be improved by supporting young children to gain a stronger understanding of the world around them. Projects aimed at increasing an interest and engagement with STEM subjects are desperately needed if future shortages in STEM professionals are to be addressed. Through early experiences with the scientific process and problem-solving, young people can be embedded with an invaluable understanding that can support their future education and career prospects, whichever path they choose.

Equally important is the work to support parents and teachers of young children who struggle with education due to behavioural problems. By finding innovative ways to support this vulnerable group, our featured researchers are tackling problems at an early stage, allowing all children to reach their full potential.

THE NATIONAL SCIENCE TEACHERS ASSOCIATION



Founded in 1944, the Virginia-based National Science Teachers Association (NSTA) is the largest organisation in the world promoting excellence and innovation in science teaching and learning for all. In this exclusive interview, we talk to Executive Director of the NSTA, Dr David Evans, head of the world's largest professional organisation representing science educators of all grade levels.

Dr Evans tell us that, 'NSTA membership – approximately 55,000 strong, and representing more than 100 countries – is the strength and foundation of the Association. Our membership includes science teachers, science supervisors, informal science educators, administrators, scientists, and leaders in business, industry, and government. Along with its members, the NSTA's 56 state chapters, 34 associate groups, 9 affiliates, and 165 student chapters work together to further promote and support quality science education.'

‘By far the biggest challenge to STEM education is the low level of science literacy in the general population.’

Tell us about the NSTA’s current goals and vision for the future?

Our focus has always been on teachers, schools, and districts, providing support from the ground up by way of face-to-face professional learning; publications filled with pedagogical tips, science content, and classroom activities; and opportunities to recognise student and teacher achievement.

Our goals for the future include raising the status of science education and science teaching as a profession by advocating for high-quality science education; enhancing the professional learning of science educators by providing a suite of tools, resources, and opportunities that support long-term growth; revitalising science education to boost student achievement and science literacy; and nurturing scientific curiosity among children in the earliest grades.

Why do you believe it’s important for all students to have access to a good scientific education and why is it important to encourage improvement and innovation in science teaching?

Science, Technology, Engineering and Mathematics (STEM) education has a big impact on the daily lives of all Americans. STEM innovation drives our economy and prosperity. We increasingly have to make informed decisions on issues ranging from healthcare to energy policy that affect ourselves, our families, and our communities. And while the creativity that drives STEM literacy, scientific discovery, engineering design, technological problem solving, and innovation starts at home, it is nurtured in the K-12 primary and secondary education STEM classroom. STEM experiences help students develop critical-thinking skills, encourage innovative thinking, and foster perseverance. Students need the kind of preparation that not only supports their learning now, but also gives them the tools and skills necessary to succeed in a continuously changing world. STEM education gives them these skills.

How are you working to raise public awareness about the importance of science education?

The NSTA works with numerous organisations to advocate for science education at the national, state, and local levels. We comment on policies and legislation; help engage teachers in advocacy; co-sponsor events such as the March for Science; provide resources and guides to engage parents in supporting their child’s science learning; and frequently provide perspective and insights to news outlets. We recently trained a cadre of award-winning teachers to be ambassadors for STEM education and work with elected officials at all levels.

What are the main opportunities and benefits you can offer your members, and how does the NSTA support teacher’s professional learning and development? Can you tell us a little about your national conferences?

Membership in the NSTA delivers all the best professional learning and resources a science educator needs. Members enjoy vetted teaching resources, discounts to online and face-to-face professional learning opportunities, skill-building webinars, and much more.

As a leader in science education, the NSTA works to engage teachers of science nationwide and improve student learning by providing professional learning products, services, and programs. The NSTA has developed a collection of digital tools and online resources to address

the needs of busy science teachers. Through the NSTA Learning Center, educators can explore content and its pedagogical implications and document their professional growth – all from the comfort of home and in collaboration with like-minded educators via our moderated online professional learning community.

Each year, the NSTA hosts a national conference, three area conferences, and a STEM Forum & Expo that attract nearly 20,000 science educators. These conferences offer the latest in STEM content, teaching strategies, and research. In conjunction with select conferences, the NSTA hosts Professional Learning Institutes (PLIs), focused professional learning that address topics in depth and promote research-based strategies to improving science education. The NSTA also hosts workshops that help participants learn how to conduct comprehensive teacher training on the Next Generation Science Standards (NGSS).

The NSTA is dedicated to helping science educators and administrators put the vision of the new science standards into action with a collection of teacher and vetted classroom resources, professional learning programs, and information and tools, all found on the NGSS@NSTA Hub.

The NSTA publishes approximately 20 books per year for science teachers and has a growing list of science books for children with accompanying guidance for both parents and teachers. Further, the NSTA publishes five peer-reviewed journals, four in print and one online.

Tell us about the Next Generation Science Standards and how they were developed?

The Next Generation Science Standards (NGSS) are voluntary K-12 science standards that promote a new way of teaching and learning that allows students to actively do and experience science in a deep, meaningful way – not just learning about it from a textbook or a lecture. The NGSS are based on the NRC Framework for K-12 Science Education, that describes the essential science content and practices that all students should learn by graduation from high school. The standards have the power to transform science education by giving all students the skills and knowledge they need to be informed citizens, college ready, and prepared for STEM careers.

Education experts from 26 states and a cadre of teachers, administrators, curriculum developers, scientists, and other stakeholders worked to develop the NGSS with private funding. The NSTA was a partner in the development process, along with Achieve, Inc., the National Research Council, and the American Association for the Advancement of Science. Eighteen states and the District of Columbia have adopted the NGSS. The NSTA is working to help states, districts, and teachers implement the standards.

Tell us how these new science standards are different in approach? Why is this change in learning strategy important?

The NGSS refine the goals for science teaching and learning by reflecting a growing body of knowledge about how students learn science. Significantly, the standards are cast in terms of what students should be able to do, rather what they should be able to recite. This new vision, as established by the Framework, recommends a number of conceptual shifts in teaching and learning. The most significant is that science and engineering practices (how science is conducted in the real world) should be used to actively engage students in science learning, and these practices should be integrated with disciplinary core ideas (content) and crosscutting concepts (broad science ideas that permeate all the sciences) in a three-dimensional nature. Other important shifts include the integration of engineering, and the need to use phenomena to authentically engage students in three-dimensional instruction.

Science education traditionally has focused on large volumes of content, primarily basic facts and vocabulary, while falling short on the deeper understanding of key scientific concepts and the application of these concepts to daily life. The new standards refocus K-12 science education to improve college preparation, STEM career readiness, and the ability of all members of society to

make informed decisions. It's also informed by the latest research on how students learn science. The NGSS will help us improve the participation and performance of America's students in science, technology, engineering, and mathematics (STEM) so that our next generation will exceed the level of innovation, problem-solving and technological advancement required in a globally competitive environment.

How is the NSTA supporting international communication and collaboration between science educators across the world?

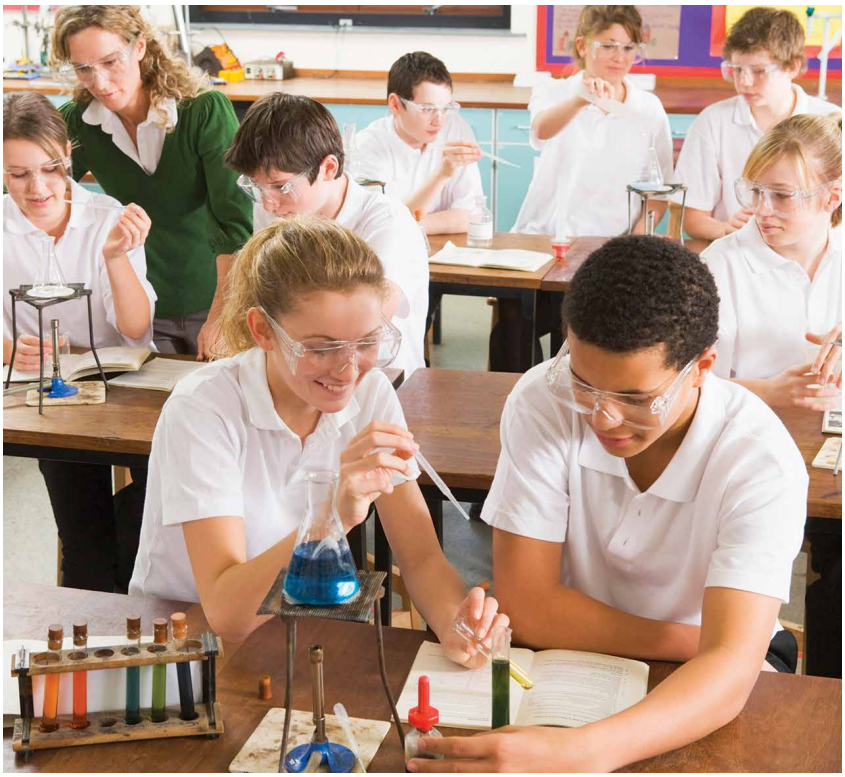
We are a national organisation, but we see our place in the larger scheme of things, where science educators the world over have much to share with one another. The NSTA has members in more than 100 countries and often hosts international science teachers at our conferences. Additionally, we welcome teacher delegations from around the world to the U.S. for various professional learning opportunities. NSTA leadership officials are often invited to speak with minsters of education and educators in many countries and NSTA books for teachers have been translated into 14 languages, from Arabic to Thai.

The NSTA believes that international science education should be a priority for all science educators. In support of this, the NSTA has an international advisory board that advises, guides, and provides input on the Association's international efforts and helps to develop strategies for implementing new endeavours. The NSTA also has an official position statement, International Science Education and the National Science Teachers Association, that can be accessed at: http://www.nsta.org/about/positions/international.aspx.

What are your views on the current uncertainties in funding for STEM education in the U.S. and the potential impact this has for the future?

Over the past few years federal lawmakers have supported STEM education because they see the value of STEM programs in their states and districts. We are certain that these decision makers will continue to support STEM education in the federal education budget and reject the Administration's funding request that eliminates or reduces funding for key K-12 teaching and learning programs.

'Our long-term plan is to implement the new science standards which emphasise the importance of demanding evidence and cause and effect reasoning over authority to draw conclusions. It will take a full generation of students before this can be accomplished but we are on the right path.'



Finally, what do you see as the biggest challenges facing educators in STEM subjects over the next decade? Tell us about your longer-term plans to tackle these challenges.

By far the biggest challenge to STEM education is the low level of science literacy in the general population. The confusion between what the science tells us about the physical world versus what decisions we make about how we live in the face of that information remains a challenge. For example, discussion about climate change, GMO foods, evolution, and vaccination is often cast in terms of scientific uncertainties when there is actually very little. This antipathy towards science is often expressed in efforts to move the science classroom away from science. Our long-term plan is to implement the new science standards which emphasise the importance of demanding evidence and cause and effect reasoning over authority to draw conclusions. It will take a full generation of students before this can be accomplished but we are on the right path.

In the near term, of course, we need support for professional learning for teachers, better physical facilities for students to learn in, and more equitable opportunities for all students. Leadership from the highest levels of government is essential and, given the unique role played by STEM in our economy, we have reason to hope for it.

National Science Teachers Association

www.nsta.org

ENGINEERING STAR: COLLABORATION BETWEEN ENGINEERS AND EDUCATORS

The Next Generation of Science Standards (NGSS) requires teachers to incorporate engineering principles into their course curriculum, even if they are not professionally trained on the subject. **Dr Mary Ann Jacobs** and **Dr Zahra Shahbazi** have developed a programme at Manhattan College titled Engineering STAR: Scholars Training and Retaining. This programme promotes collaboration between engineers and educators, to ensure that science, technology, and math teachers are adequately prepared to teach engineering topics.

Introducing Engineering to Pre-College Students

The technology sector is expanding rapidly, increasing the demand for engineers and scientifically trained professionals. Policy makers and educators have thus been trying to develop new course curricula and academic programmes, to ensure that younger generations are well-equipped to join the workforce of the future.

A teacher's learning journey should be an on-going process, with educators prepared to meet the needs of a continuously evolving classroom. However, around one third of math and science teachers in the US have never been trained on the content areas they cover in class. Roughly 30% of chemistry and physics teachers are not trained to teach these subjects and a quarter of math teachers have never attained math degrees.

Thomas Luce, CEO of the National Math and Science Initiative (NMSI) and a former assistant secretary at the US Department of Education, highlighted that a degree in math or science is not always enough. He says: 'In our mind, a certificate doesn't necessarily mean somebody has content knowledge. If you don't have content knowledge then it's very difficult to not only teach the class, but it's virtually impossible to inspire somebody.'

The *Next Generation of Science Standards (NGSS)* requires science, technology, engineering, and maths (STEM) teachers in the US to incorporate engineering topics into their course curriculum. Yet, only a few educators with a degree in engineering transition to school classrooms and most teachers have not been trained to educate students on engineering-related topics.

Ensuring that educators are well-prepared to introduce engineering concepts to students is hence of key importance, in order to provide learners with the skills, knowledge, and insight necessary to pursue further studies or careers in engineering. The Engineering STAR Scholars Training and Retaining project, funded by the National Science Foundation (NSF), is specifically aimed at preparing K-12 grade school teachers to educate students in engineering.

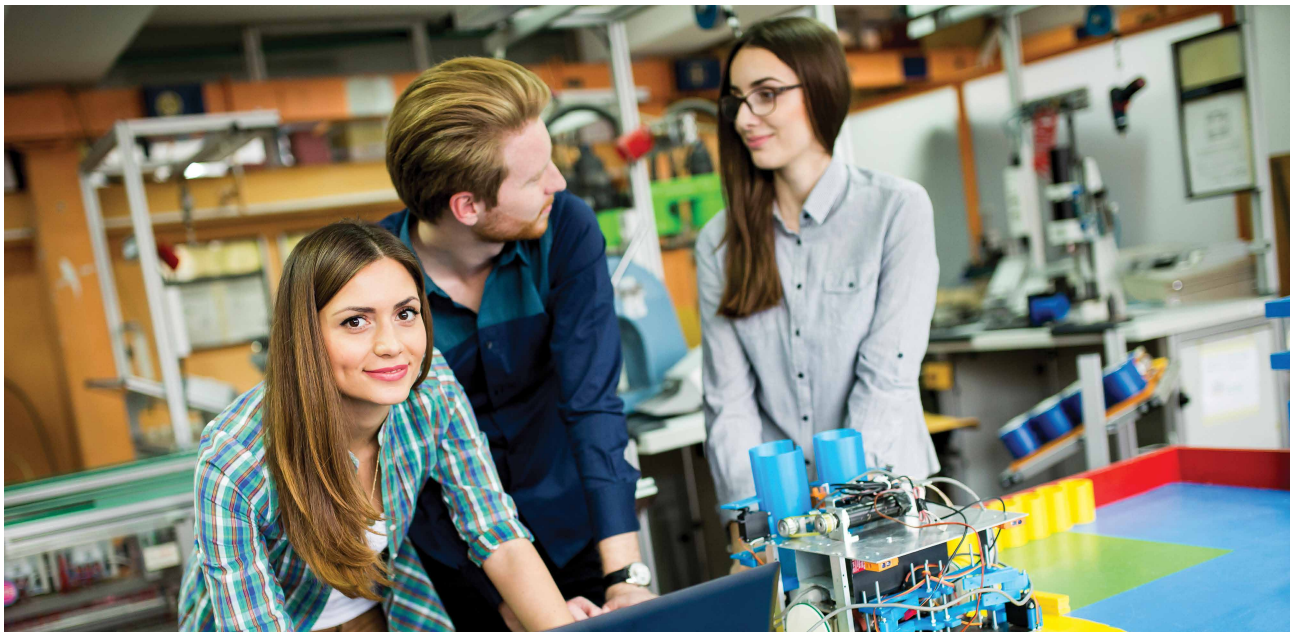
The STAR: Scholars Training and Retaining Project

The STAR Professional Development programme, a component of Manhattan College Engineering Scholars Training and Retention (STAR), was developed by a group of professors at Manhattan College, led by Dr Zahra Shahbazi and Dr Mary Ann Jacobs. The STAR Center provides a way for elementary, middle and high school teachers to delve into engineering education, through a series of mini-workshops and group activities led by college engineering professors.

'A major goal for our NSF STAR grant was to make possible a collaboration between engineers and educators,' explains Dr Jacobs. 'Currently, these two fields are separated by State requirements for certification, which are mutually exclusive. Yet the realisation that our students today need a full view on STEM requires that these two groups work together to make this possible, as we prepare our current students to take their places in STEM fields.'

The STAR project explores ways to promote engineering education for three distinct groups of learners – engineers and engineering

‘This programme made possible a collaborative initiative among current educators, engineering professors, and those studying to become the next generation of engineers and educators.’



students, elementary, middle or high school students, and college students pursuing a degree that will allow them to teach in K-12 schools. The project’s goal is to train STEM educators on how to teach engineering to younger students, by providing them with the opportunity to be trained and collaborate with qualified engineering professors.

The STAR Center additionally offers three newly developed academic programmes – a minor in education for engineering students, a certificate in engineering education for STEM majors pursuing a teaching qualification, and a post-baccalaureate certificate in engineering education for engineering graduates.

The NSF-funded project provides professional development opportunities for STEM educators and trains selected groups of university students on how to deliver hands-on workshops to underrepresented student groups in local schools, encouraging the latter to pursue future studies in STEM-related fields.

Encouraging Collaboration Between Educators and Engineers

The STAR project is based on the belief that greater collaboration between engineers and educators could help in developing more effective ways of introducing engineering principles within classrooms. ‘Engineers need to understand ways to educate students in engineering fields of interests and educators need to have some background in engineering,’ says Dr Jacobs. ‘This programme made possible a collaborative initiative among current school educators, current engineering professors, and those currently studying to become the next generation of engineers and educators.’

The Professional Development programme at Manhattan College included three full-day workshops, during which teachers worked collaboratively with engineering professors. The educators and engineers formed a partnership to create effective and dynamic lesson plans, in order to promote inquiry, problem solving skills, and hands-on activities in classrooms in engineering topics.

After the workshops, the Professional Development programme continued with the development of lesson plans, which are ultimately shared through the STAR website. The engineering professors assist and guide educators on how to best apply their newly devised lesson plan in the classroom.

Another aspect of the STAR project is the Engineering Ambassadors programme, a collaboration between undergraduate students and faculty members aimed at introducing K-12 grade students to STEM-related occupations.

Engineering and education undergraduates are mentored by faculty members in designing lesson plans that introduce younger students to the field of engineering and thus encouraging them to pursue further studies and careers in this area. The undergraduates participate in workshops that assist them in developing skills in public speaking, teaching techniques, and collaborative work skills.

The Engineering Ambassadors practice their developed lesson plans to prepare for visits to local K-12 schools. During the visits to these schools, which are mainly financially disadvantaged schools that serve underrepresented minority students, the Ambassadors present to the students an overview of engineering and provide at least one hands-on activity to engage students in an engineering activity.

Evaluating the Project’s Outcomes

The STAR Professional Development programme was first introduced in 2015, with approximately 18 participating educators every year. The teachers were recruited from 40 schools associated with the College through the School of Engineering or the School of Education. To evaluate the effectiveness of the Professional Development programme, participating teachers and engineering professors were asked to complete a survey, which asked them to rate the workshops and describe what they felt were the most satisfactory and unsatisfactory aspects.

The responses collected were positive, with most teachers highlighting that they appreciated working with engineering professors in small groups, as this allowed them to ask questions, consider real-life applications, and communicate with colleagues about teaching engineering concepts. Many teachers also reported enjoying hands-on experiments and keynote speakers' suggestions of how to best incorporate engineering and STEM-related topics into their course curriculum. Some mentioned that they would have enjoyed more time working with the engineering professors.

Overall, participating educators praised the programme, saying that it had increased their confidence in teaching engineering topics and provided excellent ideas on how to teach difficult concepts. The engineering professors who participated in the STAR programme said they largely appreciated communicating with the teachers and learning about the challenges they face in incorporating challenging STEM-related topics in their classes.

The feedback collected highlighted ways in which the programme could be improved – for instance by asking teachers to select topics covered in the workshops or by proposing ways for them to touch on particular areas with more affordable materials, should their school have a limited budget.

To evaluate the Engineering Ambassadors programme, the STAR organisers collected feedback from participating college students, as well as from middle and high school students during school visits. The students' responses were generally positive, with most younger students saying that the ambassadors' visit had helped them to understand the work of engineers and had taught them new ideas. The undergraduate ambassadors felt that the programme had enhanced their communication skills and creative thinking, while also teaching them the importance of introducing engineering to younger generations.

Preparing Educators to Teach Engineering Topics

The growing need for qualified engineers is placing greater pressure on policy makers and educators to develop effective academic programmes that introduce students to engineering from an earlier age. The new engineering content requirements included in the *Next Generation of Science Standards (NGSS)* highlight the need to train teachers on how to best teach engineering to their students.

Whether by introducing engineering-specific courses or by incorporating engineering concepts within other STEM-related subjects, many schools in the US are trying to find ways to introduce students to this increasingly important field. Initiatives such as the Engineering STAR Project at Manhattan College are extremely valuable, as they could help teachers to meet the evolving needs of their classroom, ensuring that they are adequately prepared to teach engineering concepts.

In addition to offering workshops for educators, the STAR programme also includes courses for undergraduate engineering or education students, which also promotes collaboration between the two disciplines. 'The programme is at the beginning stages as the number of students participating in it is minimal,' says Dr Jacobs. 'We need to make more readily available information on the programme and develop cohorts of students to complete the programme.'

The researchers are also looking for new ways to move forward on their quest to encourage collaboration between educators and engineering professors. 'We need to continue our collaboration among teachers in the field and our Engineering Professors,' says Dr Jacobs. 'On-going professional development in this area needs to be planned and additional financial sources need to be secured beyond the grant.'

Past research and collected data revealed that many current primary, middle, and high school teachers have never been trained on the STEM-areas they cover during their lessons. This makes it harder for them to effectively explain the course material, and even more challenging for them to inspire their students to pursue further studies in STEM-related fields. Dr Jacobs says, 'it is important to convince the State Departments of Education of the need for STEM teaching certifications, so that interested teachers and engineers can be better prepared to meet the needs of our students.'

Meet the researchers

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Mary Ann Jacobs, is an Associate Professor in the School of Education at Manhattan College, Riverdale, NY. She earned a BA degree in teacher education from Felician College, a MS degree in educational administration from Manhattan College and an EdD in education leadership from St Mary's University of Minnesota. She prepares secondary teacher candidates in all content areas through her courses in secondary pedagogy. Her areas of interest include STEM education, brain compatible strategies and action research in the classroom.

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Zahra Shahbazi is as an Associate Professor of Mechanical Engineering at Manhattan College. She earned a BS degree from the University of Tehran in Mechanical Engineering, an MS from Amir Kabir University of Technology in Biomedical Engineering and a PhD degree from the University of Connecticut in Mechanical Engineering. She has also received a certificate in college instruction from the University of Connecticut. She has conducted extensive research on computational modelling of protein molecules, additive manufacturing and engineering education. In 2014, she received two National Science Foundation awards from the Robert Noyce Teacher Scholarship and Scholarship in STEM programs.

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FUNDING

US National Science Foundation

FURTHER READING

Z Shahbazi, AE Lehnes, MA Jacobs and KC Mancuso, Engineering Ambassadors: Bridging the Gap between Engineering and Education Undergraduates and Middle and High School Students, ASEE Annual Conference & Exposition, New Orleans, LA, 2016

MA Jacobs, Z Shahbazi, A Scotti, KC Mancuso AE Lehnes, From Professor to Teacher: Who Knows What Engineering Is Best in the K-12 Classroom? ASEE Annual Conference & Exposition, Columbus, OH, 2017

THE FUTURE OF ENGAGEMENT IN INFORMATION TECHNOLOGY

As many industries, government agencies and community organisations incorporate Information Technology solutions into their business process, the need for skilled diverse talent continues to grow. A dedicated team at the University of Cincinnati is addressing this with a program of Design Based Information Technology Learning Experiences (DITLE) to design diverse experiences to promote and study high school students' engagement in information technology.

Indispensable Information Technology Throughout Society

Over the past few decades, a wide variety of scientific and technological advances have been transforming society and professional settings. The Information Technology (IT) field is in constant growth, leading to a greater need for technology professionals to cover what are now among the most highly paid roles in many countries worldwide.

Currently, 51% of Science, Technology, Engineering and Maths (STEM) related positions are those that require advanced knowledge of computers and software. These include roles such as Information Security Analysts, Software Developers, Computer Network Administrators, Database Administrators and many more.

STEM education has become more important than ever, to ensure that the workforce of the future is well-equipped to face the challenges of modern society and that those who wish to pursue a career in technology have been provided with the necessary tools early in their academic path.

While most IT jobs require post-secondary education, students' preparation in technology should ideally begin before college. An early acquisition of basic IT related skills can considerably improve young people's chances of succeeding in relevant higher education courses, while also broadening job possibilities for high school graduates who are not in a position to immediately move on to college.

The University of Cincinnati, Ohio, has therefore developed Design Based Information Technology Learning Experiences – DITLE, an academic program that introduces high school students and teachers to basic IT skills. Through a variety of learning experiences, the DITLE project tries to increase secondary students' interest in and awareness of IT related topics, while improving their preparation and broadening their prospects for the future.

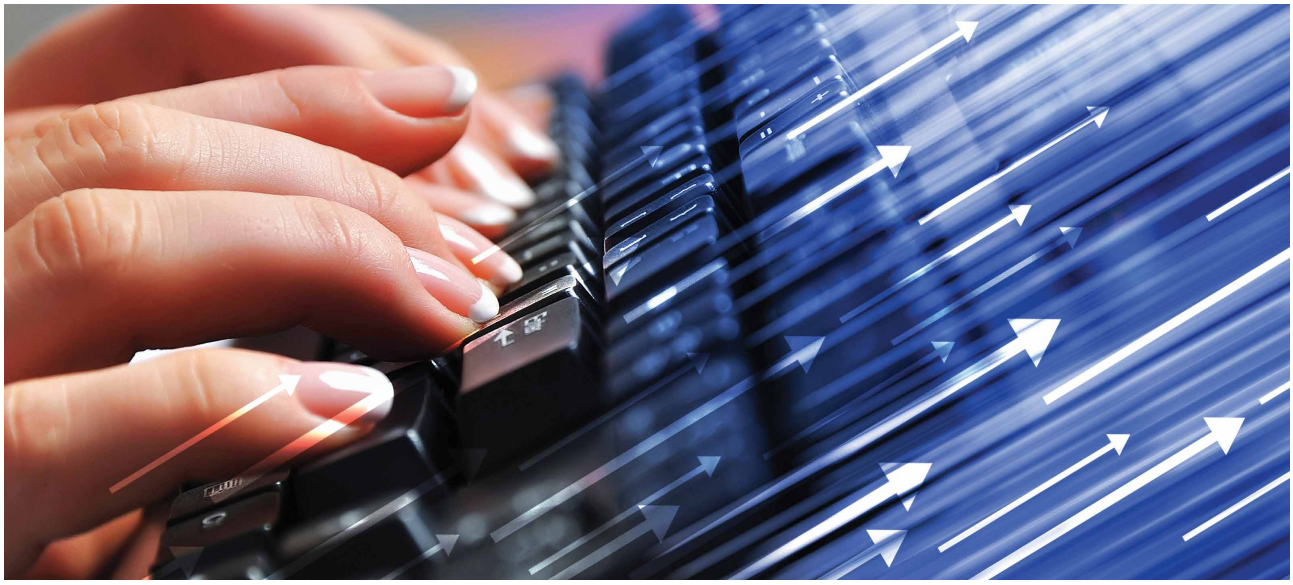
The DITLE Program

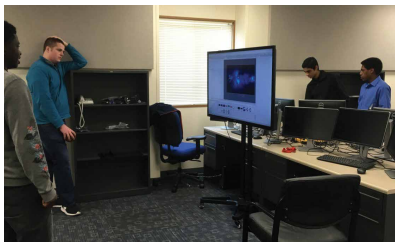
The DITLE program was developed by an interdisciplinary team from the University of Cincinnati School of Information Technology and the School of Education including Dr Chengcheng Li, Dr Helen Meyer, Dr Hazem Said, and Dr Marcus Johnson. The project was managed by Rebekah Michael, who is an experienced professional with 14 years in developing and managing software projects. They explain that, 'through a variety of hands-on learning experiences, the DITLE project tries to increase secondary students' engagement in IT related topics, improving their preparation and broadening their prospects for the future.'

The program was introduced in 2015 with 38 students participating in a summer camp and many more participating in IT clubs throughout the year. The number taking part in the summer camp has been increasing, with 49 students in 2016 and 52 in 2017. The 4-year project, funded by the National Science Foundation (NSF), involves

a collaboration between teachers, students, faculty members, industry partners of the University of Cincinnati, and businesses in the Cincinnati area.

‘Through a variety of hands-on learning experiences, the DITLE project tries to increase secondary students’ engagement in IT related topics, improving their preparation and broadening their prospects for the future.’





A number of local high schools are participating in the program including Aiken High School, Hughes STEM High School, Oak Hills High School, Shroder Paideia High School, Taft Information Technology High School, Walnut Hills High School, and Withrow University High School. The program offers high school students an intensive summer camp, an opportunity to network with other students interested in IT, and the chance to start applying their skills in community projects and paid internships within the IT sector.

The course material is based on specific background literature for teaching Information and Communications Technology (ICT) and STEM related topics. The model consists in training students to solve problems with Design-Based approaches, a subtype of Problem Based Learning methods. Design-Based methods foster students’ creative thinking and communication, developing their interest in ICT while strengthening their ability to grasp relevant mathematic processes.

These learning strategies ask students to apply their skills in ways that are authentic and related to real-world problem solving, in contrast with more traditional teaching methods that provide knowledge without testing its practical applications. Students on the program gain access to experts in the field and are provided with the opportunity to learn from experienced college professors and IT business leaders.

A Variety of Learning Experiences

The DITLE program offers high school students the possibility to participate in a variety of interesting learning experiences. At the University of Cincinnati Information Technology Day Camp, students fully immerse themselves in learning activities related to app development, cyber-security, building computer networks and much more.

The University of Cincinnati Information Technology Expo is a chance for them to develop their own mobile games, apps, robots, or work on other IT-related projects, with the option of presenting these in a competition. The Expo includes presentations by guest speakers and undergraduates in the university’s IT program. It is a great opportunity for DITLE participants to network with experienced IT professionals and older students pursuing degrees in STEM subjects.

The ICT Summer camp consists of a series of courses that allows the students to explore ICT related topics further. Students benefit from keynote speakers who are experts in their field talking about diverse topics including, ‘For the Love of Programming’ by Butch Wesley who is a Senior Developer at General Electric, ‘Playing Games is Research’ with Dr Guo Freeman from the University of Cincinnati and ‘One Woman’s Journey in IT,’ with Jen Martin PR Representative of Girl Develop IT.

The students at the summer camp are guided in a series of learning activities and projects by college students. A diverse range of activities include an ‘Agile Principles Learned Through Lego Group Activity,’ a ‘Create a College Budget’ activity and also how to, ‘Create Art by programming in Java.’

Groups of four-five students work together to create an IT solution or research project of their choosing guided by a college student as a mentor. Projects include designing an Android app that will find your location and will give a list of available radio stations for a genre of music, a home security system for under $100 using a Raspberry Pi, and an on demand greeting card printer to replace the greeting card areas of stores.

The college students stay with the high school students throughout the day, taking them on tours of the campus and leading some of the lessons. This allows them to gain valuable experience and learning credits for taking part in the program.

Beyond the summer camp the DITLE program also includes mentoring and job shadowing from Cincinnati business leaders, through internship opportunities offered at the Information Technology Solutions Center.

The DITLE program also organises community events at participating high schools, bringing together students and parents from the local community to share ideas. Students organise family and community IT events at their local high schools and in community centres to teach others the information technology skills they have learned, such as Microsoft Excel and programming.

At specially organised community nights, students share their learning and skills with others in their community and at coding nights students can take a turn at teaching community adults about coding. Finally, the After-School IT Club provides a space in which the students can work on their own IT projects that they can later show to their families, friends and other community members during specifically tailored Family Nights.

Measuring Engagement

Research associated with the program is looking into new mechanisms for expanding student engagement and participation in the various program activities and how that relates to the different abilities of the students' and their different demographic backgrounds. The team are working to understand the experiences that support student success in ICT careers and they are aiming as a result of their analysis to find new ways to broaden the demographics of students pursuing ICT careers.

The team are also gathering information that could be useful to devise future program strategies. They are collecting both quantitative and qualitative data from high school students who had been part of the program, through individual interviews, observations, and the administration of relevant questionnaires.

Focus groups that took place during the school year served as a chance to observe any changes in the students' knowledge, attitudes and interest in IT. Observations were made during the program and semi-structured interviews were carried out with up to six high school students for every year of the program and ten students from the 2017 cohort to further assess the program's impact.

The program has increased in popularity over the years, with more students joining after 2015 through referrals from family, friends, and school. It was found to have high attendance rates, with 87.9% of students being present on any given day in 2017. Those participating in the program were consistently pleased with the new relationships they formed, their group projects, and the completed activities were generally perceived as useful and valuable, improving their confidence in ICT related areas.

Students often reported that hands-on activities were the most engaging and useful, while assessments of their growth suggested an improvement after attending courses and events. Overall, the program appeared to increase the students' confidence in themselves and in their acquired skills, with many suggesting that they felt more competent and empowered.

The process of measuring student engagement is helping to shed light on areas of the program that could be improved, for instance suggesting the potential benefits of a greater focus on the hands-on projects that were particularly popular among students.

Building the Workforce of the Future

The fields of technology and science are developing at an increasingly fast pace, placing responsibility on education to ensure that the workforce of the future is equipped with all the skills necessary to meet the needs of modern society.

As society's reliance on technology increases, introducing students to the basics of information and computing technologies before they decide whether to pursue higher education is of growing importance. In-depth IT courses for high school students are still considerably rare, but projects such as the DITLE program could play a central part in preparing younger generations for a career in IT.

The DITLE program is an important initiative that has already opened great possibilities for many high school students in Cincinnati who are interested in IT, increasing awareness of IT in a number of local high schools and presenting opportunities for students to take their first steps into the field.

The project has revealed that project-based active learning is more effective in engaging diverse students and that female and minority students are more likely to engage in IT through hands-on learning activities. It also supports the use of credentialed active learning activities to play a role in increasing the scale and diversity of the IT talent pipeline.

The University of Cincinnati will be continuing with the summer camp in the coming year and local teachers will also have the opportunity to attend, to learn more about the fundamentals of IT. They can then develop new ways to incorporate what they have learned into their science or maths classes. The teachers will also be given the opportunity to work with or lead IT clubs at a partner school.

There is a national and global risk of facing a shortage of skilled technology workers in the years to come, so projects such as the one developed by the University of Cincinnati could be a substantially enabling resource for local communities. Such projects can act to increase the numbers and diversity of students engaging in information technology and pursuing successful careers in this field.

Meet the researchers

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Dr Chengcheng Li is an associate professor and assistant director for graduate studies at the School of Information Technology at the University of Cincinnati. He has over ten years of experience with teaching information technology in higher academic environments. He has carried out multiple research projects and has been part of two Review Panels for the National Science Foundation (NSF). He is the director of the UC Center for Academic Excellence in Cyber Defence.

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TEACHING A COMPUTER TO SING

As technology permeates more and more aspects of our daily lives, computer literacy and computer programming skills are more valuable than ever in the workplace. **Professors Jesse Heines** and **Daniel Walzer** of the University of Massachusetts Lowell are working at the intersection of music and technology to engage middle school students in learning computer programming by 'Teaching a Computer to Sing'.

Computer literacy has become a critical component of modern life, as computerised 'smart' technology continues to become a part of many everyday tools. The ability to write computer code is highly valuable in the workforce and the demand for programmers is expected to continue to rise over the next few decades. Despite a worldwide need for skilled programmers, many students are not introduced to computer coding concepts until college.

Early exposure to computer programming principles can help students gain confidence in working with technology and prepare them to compete in the job market of an increasingly technology-driven society. This jump start can be particularly important for young women and minority students, who are underrepresented in science, technology, engineering and mathematics (STEM). Diversity in technology leads to more unique innovations to solve the problems humanity faces – helping students see themselves as 'technical' early in their educations can greatly impact how they perceive and pursue STEM careers as adults.

In an effort to broaden understanding of STEM concepts, many educational researchers have taken interest in the intersection of STEM and the arts. Recent efforts have sought to connect visual art, theatre, music and literature with modern technology and mathematics to increase our understanding of the arts and to identify potential educational avenues between subjects that often seem unrelated. These efforts have demonstrated that music and computer programming complement one another well and are particularly amiable to adaptation for the classroom.

Music holds almost universal appeal to students of all ages, and its underlying structure often translates well into a variety of computer programming languages. Heines and Walzer are developing the innovative program, 'Teaching a Computer to Sing' or TACTS, that is engaging middle school students in both technology and the arts by teaching them to translate music into computer code.

Walzer describes how, 'our work focuses on teaching basic computer science concepts to students who might never take a formal course in computer science or computer programming. We do this through music, showing students connections between the structure of music and the structure of computer programs.' They have spent the past two years piloting TACTS as a middle school after-school program, and their results show promise for combining STEM education with the arts.

Overcoming Educational Obstacles

The overarching goal of the TACTS curriculum is to increase students' understanding and confidence in both music and computer programming. The concept was originally designed and implemented with undergraduate students, and the course has enjoyed great popularity at the college level. Heines and Walzer hoped to adapt the program to meet the needs of younger pupils and to accommodate the often more limited resources available within a typical public middle school classroom.

One of the major aims of the pilot study was to identify potential challenges of teaching

in the school environment and to modify the structure of the program to provide the best learning experience possible for younger pupils. The TACTS program ran for 2.5 hours twice a week after school, offering long blocks of learning time, but at a time of day that might prove difficult for student attention span. On a typical afternoon in the program, students spend the first hour singing and learning music, take a short break, and then spend the rest of the day on the computer coding.

The team recognised that getting children to pay attention to any kind of learning exercises after they had already spent seven hours in

‘Our work focuses on teaching basic computer science concepts to students who might never take a formal course in computer science or computer programming. We do this through music, showing students connections between the structure of music and the structure of computer programs.’

school was going to be a challenge. They partnered with a seasoned middle school music teacher, who was already well-liked by the students and experienced in getting distracted kids involved in group activities.

Even with the music teacher’s help, they still found that it was a struggle to keep the kids engaged in large group activities. They eventually recruited multiple university students to act as teaching assistants, creating a high student-teacher ratio that allowed for teachers to interact with students in pairs.

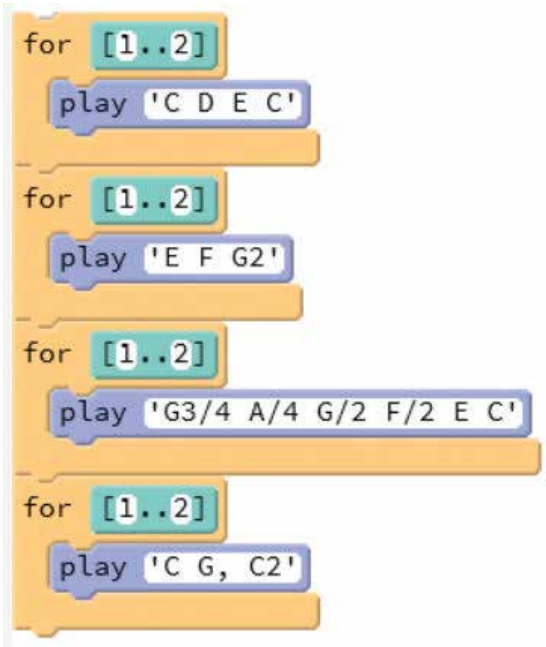
The college age teaching assistants contributed to a more clubhouse feel for the program, where younger students were able to bond with college students as role models while receiving more individual attention. In the first year, with mostly male teaching assistants, the TACTS team quickly recognised that the group of primarily female students responded most strongly to female teachers, and that their female teaching assistants were able to provide valuable insights into what middle school girls were going through. In the second year they hired more female teaching assistants to better replicate the gender ratio of students in the program.

Access to technology also proved to be a major problem that the TACTS team had to overcome. While their undergraduate course typically consisted of students with their own laptops, many of their middle schoolers did not have access to a computer at home and were reliant on the machines provided by the school.

This was further complicated by the fact that the school-owned computers were equipped with security measures to prevent students from installing software on the computer. To circumvent these issues, Heines and Walzer identified music and coding programs that could be used as cloud-based software from any computer with Internet access. This vastly increases the flexibility of the program and means that any school can easily implement the program within a tight budget.

Learning the Harmony

Previous research has suggested that education focusing on the intersection between STEM and the arts could help students learn more about both subjects. In the initial pilot of this program, Heines and Walzer wanted to determine if an interest in understanding music could facilitate learning to translate a song into computer code and



Frère Jacques in the key of C.

if working with the individual parts of a song could also help students learn how to sing multi-part harmonies.

Music is usually more familiar to students than the language of computer programming. The TACTS team expected that it would be easier for the students to initially focus on learning the song before transferring it into code after they had a firm understanding of the music. Walzer summarises the philosophy underlying starting with music: 'This approach tries to make the abstract concepts of computer science more concrete and thus easier for students to understand.'

Before students can begin translating songs into code, they must first understand the musical components of a song. Initially the TACTS team started with popular pop songs, working with a music arranger to simplify the complex harmonies into more manageable compositions.

Early into their pilot they found that despite their best efforts, students were struggling with the complex rhythms of the pop songs. At the suggestion of the TACTS music teacher, they shifted to partner songs, which are simpler songs designed to help students learn how to sing in harmony. As part of their music education, the students get to enjoy demonstrations of people using the musical concepts they are working on in the program. Many of the undergraduate teaching assistants are music majors and occasionally performed for the class.

TACTS has also brought in an *a cappella* group to demonstrate the possibilities of multipart singing. These visits served to both educate the students about music and to inspire them to keep working on their own compositions in the program.

Programming a Song

Perhaps the biggest challenge of the TACTS program was selecting an appropriate coding language for middle school pupils. Heines and Walzer started with the Scratch programming language and MIDI music notation. This required students to first identify a musical note's alphabetical name and then convert it into a corresponding MIDI numerical code.

In this notation, the code bears little resemblance to sheet music, and it is harder to identify on paper. The students were struggling with this conversion, and the TACTS team felt that they would make more progress with a simpler language. They switched to EasyABC notation, which more closely resembles common musical score format, and started using the Pencil Code environment to play the resulting sequences.

Students had a much easier time connecting the dots with these programs. These tools are available online and can be used on a website without installing anything on the computer, making them ideal for use on school machines with tight restrictions on software installation.

One of the greatest benefits of writing code for music is that students can immediately play back their coded score and observe tangible results of their programming work. Unlike many coding applications where mistakes can be difficult to identify, students can simply listen to the output of their programs to find the places where the code is not working. They are in effect learning to code through play, mistakes in the code are easy to hear, and successes are instantly rewarded.

For trickier song segments, the high student-teacher ratio allowed the TACTS team to be readily available to provide support and help students work through coding challenges. In the second year of the pilot, TACTS introduced a third program called Soundtrap that permitted students to incorporate a broader range of recording tools and sounds and gave them the opportunity to learn a second coding language format. This allowed second year students to take more creative license with the digital music they were creating while also letting them apply their coding skills to a more advanced project.

A Bright Future for TACTS

The ultimate goal of the TACTS program was to facilitate student learning in both music and computer programming. The results of the initial pilot study show promise for implementing teaching programs at the intersection of art and science. All of the participating students learned basic coding skills and demonstrated an understanding of the foundations of computer programming.

Students also learned to sing in three-part harmonies, surpassing the music teacher's expectations for what was possible in their age group. When asked about their perception of music and their own music abilities, students that participated in the program indicated that they both perceived music more positively and saw themselves as more capable than when the program began.

When asked the same questions about programming, most students perceived programming about the same as at the start of the program, but the majority felt much more confident about their own ability to write computer code.

Walzer notes, 'just as our work has built on that of others, our work has been picked up by other educators and adapted and extended for their own school and college environments.' They are excited to see the flexible program sing out in classrooms across the nation.

Meet the researchers

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Jesse M. Heines began his journey in academia with a Bachelor of Science in Earth Sciences from the Massachusetts Institute of Technology in 1970. He continued on to earn a Doctorate in Education specialising in Educational Media and Technology from Boston University in 1979. He has over 30 years of practical experience working in computer-based instruction development. In 1985 he joined the Computer Science faculty at the University of Massachusetts Lowell and retired a Professor Emeritus in 2016. He has won awards for excellence in computer science teaching and published over 40 peer-reviewed papers on computer-based learning. For more information and resource materials on the TACTS program, please see https://jheines.github.io/tacts/Workshops/.

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A JOURNEY THROUGH THE OCEAN: A MODERN APPROACH TO SCIENCE EDUCATION

Research in the sciences is currently undergoing a massive transformation, as technological advancements shift big data into the forefront of investigative tools, and early education is looking for solutions to keep up. The **Ocean Tracks** program offers a structured learning tool that supports both students and teachers in tackling big data in the classroom.

As technology advances and more professions are requiring data skills, our education systems are working hard to keep up and prepare students for this new workforce. Although complex datasets are often widely available to teachers, it is a challenge to make big data student friendly.

Indeed, the forms that big data takes are often far from user friendly, due to cryptic labelling of measurements, unintuitive navigation through data repositories, complicated visualisations, and highly involved analytical requirements. Further, teachers are also often unfamiliar with big data analysis techniques, particularly at introductory high school levels. These barriers make it difficult for the average high school instructor to either teach or assess a comprehensive lesson using big data. There is a genuine need for a user-friendly data interfaces and curriculum to guide students and teachers through big data and empower them to answer their own inquiries with reassuring guidance.

The Ocean Tracks program, developed by Randy Kochevar, Kira Krumhansl, Ruth Krumhansl and their colleagues, is a novel program aimed at engaging students in working with big data, using a subject matter that many students naturally gravitate to – charismatic marine animals. The program represents the hard work and efforts of a National Science Foundation funded interdisciplinary team of marine biologists, oceanographers, curriculum developers, web designers, teachers, and education researchers.

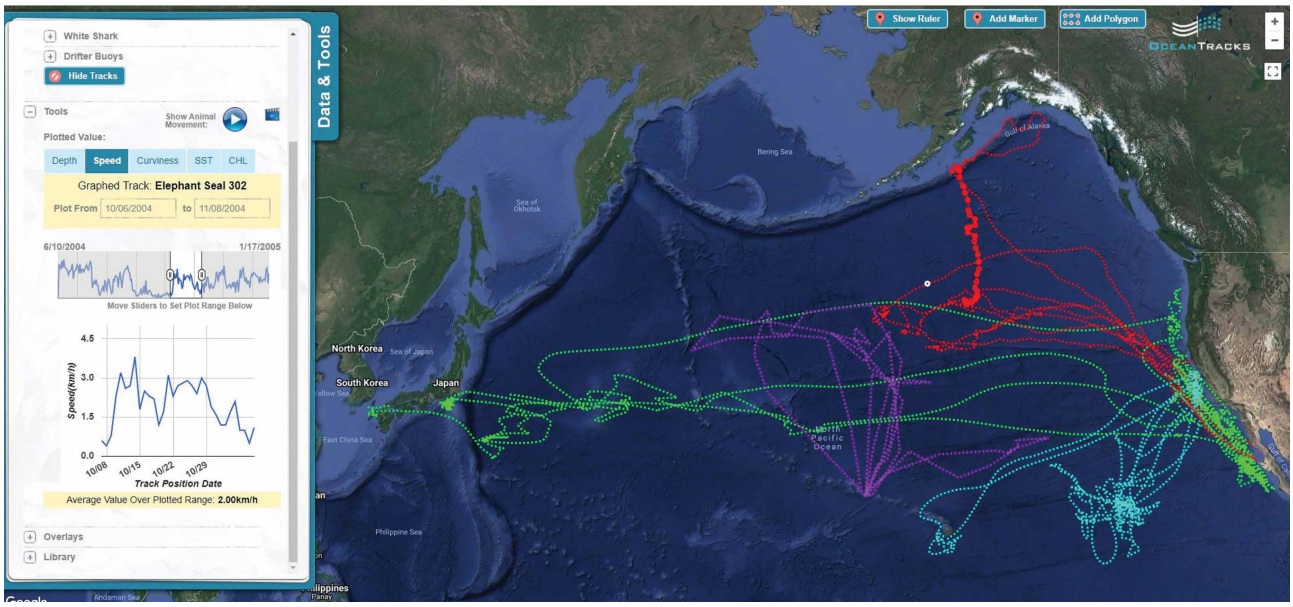
The Ocean Tracks web interface gives students and teachers access to large, professionally collected datasets of marine animal migrations and ocean conditions, complimented by structured learning modules that empower students to navigate the data in pursuit of answers to questions with real life relevance. As Ruth Krumhansl explains: 'We've pushed to build on and move students beyond the work with data they have traditionally been doing in classrooms, and to engage them with the more *complex* data sets and problem-solving strategies that are at the core of today's "big data"-driven workforce and society.'

A Novel Approach to Presenting Big Data

The data provided in Ocean Tracks is described as CLIP: complex, large, interactively-accessed, and professionally-collected. Complex data includes multiple kinds of data types, collected using a variety of instruments and methodologies, which are not necessarily normalised or correlated with one another at the onset. The dataset is *large* in that it includes far more data than is necessary to approach any single question or hypothesis, offering students the opportunity to get creative with their questions, but also the challenge of homing in on what is critical to their research goals, while rejecting the rest.

The data in Ocean Tracks is *interactively-accessed* as users have choices about what data to analyse and how to do so, along with options for how to visualise a given dataset. Finally, the data is all *professionally-collected* – it is the result of hundreds of marine biologists, oceanographers and climate scientists collaborating to provide a dataset that is far beyond what the students could generate on their own in a

‘We’ve pushed to build on and move students beyond the work with data they have traditionally been doing in classrooms, and to engage them with the more complex data sets and problem-solving strategies that are at the core of today’s “big data”-driven workforce and society’



typical classroom experiment. Access to CLIP data is blossoming across multiple fields, offering students a window into vast astronomy measurements, images of outer space, weather and climate data, biological measurements from ecosystems around the world, and more. The task posed to distributors of CLIP data is providing not only access, but scaffolds to help students make sense of the plethora of information.

Starting with a comprehensive database of measurements from scientists around the globe, the Ocean Tracks team collaborated to build an intuitive web interface, complete with learning modules and teaching resources.

As a result, teachers are offered multifaceted support in leading Ocean Tracks modules, while they can also give students a degree of freedom to pursue questions that align with their personal interests.

The program was piloted in high school science classrooms in 2013 and undergraduate classrooms in 2015–2016. The efforts and experiences of pilot teachers have provided numerous insights that have further shaped the program into a ground-breaking educational tool over the past five years. This groundwork has demonstrated the potential of such programs to facilitate advanced scientific and quantitative analysis using big data in high school classrooms. ‘We’ve come to appreciate the complex relationship that exists between interface design, curriculum development, teacher professional development, and student achievement,’ says Kochevar, co-founder of Ocean Tracks. He hopes that the lessons learned from this program will inspire other research groups to build similar programs.

Bringing Charismatic Megafauna into the Classroom

Through the Ocean Tracks modules, students are exposed to concepts in marine biology, oceanography, and ecology, while also developing core data literacy skills. The learning modules take students through authentic scientific investigations of the data, driven by the same questions that scientists in the field are currently asking with the same data sets.

To hook students in, the program starts with a subject that holds near universal appeal to students – uncovering the long-distance migrations and behaviour of four species of charismatic marine megafauna – great white sharks, northern elephant seals, Laysan albatross, and Pacific bluefin tuna.

Through the efforts of collaborating marine biologists, these animals are tagged with special electronic instruments that record factors such as location, depth, water temperature and salinity. Some of these tags even beam this data to satellites every time the animal comes to the surface. This data is offered in conjunction with datasets from Earth-orbiting satellites showing oceanographic variables such as temperature and sea surface chlorophyll concentration (a proxy for primary production), as well as a map of the intensity of human impacts in the world’s oceans.

Students are able analyse migrations of their animal of interest, and begin to ask questions about why these animals travel where they do, and form hypotheses about what motivates their migrations and where they might go next. Unlike traditional classroom experiments, which are often heavily work intensive for the instructor and limit students to a constrained set of questions, Ocean Tracks offers the classroom access to a rich

dataset, which allows for exploration and spurs meaningful in-class discussions.

High school science teacher Mueller-Northcott described her students' remarkable engagement and deep focus in their Ocean Tracks work. 'This was not the kind of discussion that we have very often in my marine biology course,' she said. 'When confronted with variation in their measurements and conflicting claims, my students helped each other grapple with issues such as what constitutes evidence, what the data (and differences in the data) actually represent, the significance of patterns, and the meaning of data that don't fit those patterns, and how to assess confidence in your own and others' claims and evidence.' Before her eyes, students gained incredible depth of understanding in how to approach scientific questions, and simultaneously learned how to contend with the massive and often variable datasets that big data brings to the table.

The Only Limit is Imagination

The possible lesson pathways in Ocean Tracks offer a diverse exploration of intriguing and relevant core learnings. Students begin with an oceanography lesson that helps them understand how physical and chemical oceanographic conditions and processes determine which parts of the ocean are most rich in life. Students then explore animal tracks of a single and multiple species to determine where oceanic 'hotspots' occur, or areas with high biological activity.

Students are then guided through a module where they work with data that overlays human impacts, such as pollution and fishing, with their species' hotspots. This helps illuminate the role that human beings play in changing ocean ecosystems. The learning modules culminate in an activity that engages students in creating the design of a Marine Protected Area for their species of interest, developed using data investigations of biological hotspots and human activities.

The learning modules were designed primarily as tools to teach core data literacy skills within the context of course content in Marine Biology, Ecology, and Oceanography. The data skills practiced by students in Ocean Tracks include skills such as evaluating data to identify issues of data quality, identifying and describing data patterns, developing conclusions using data as evidence, and evaluating alternative explanations for data. Many of the skills emphasised in the modules are categorised as Critical and Analytical Thinking – identified as being of primary importance in today's educational system.

Opportunities for independent investigation in Ocean Tracks are limitless. Once students have begun to master the core skills and concepts necessary for further exploration, they can begin to dive into the vast array of Ocean Tracks data to pursue their own questions of interest. The data can be used to investigate hypotheses ranging from the effects of climate change on the location and use of biological hotspots to sexual differentiation in the feeding and migratory behaviour of white sharks.

As teacher Mueller-Northcott describes: 'Their enthusiasm as they started this module was a testament to the engaging nature of the Ocean Tracks data and curriculum module itself, and the impact of giving students a challenging task that motivates them to want to rise to the challenge. I am excited to see the work they are going to produce!'

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THE STEM EDUCATION COALITION

The STEM Education Coalition was founded more than 15 years ago with a mission to raise awareness in the U.S. Congress, the administration, and on the state level about the critical role that STEM education plays in enabling the U.S. to remain the economic and technological leader of the global marketplace in the 21st century. In this exclusive interview, we have had the pleasure of speaking with Lindsey Gardner, Director of External Relations for the STEM Education Coalition, who tells us about their mission to engage more stakeholders in working together to promote and support improvements in the way students learn about science, technology and engineering. She tells us that, 'as a non-profit organisation we currently have over 700 members across the country. Our members include Fortune 500 companies, teachers' organisations, professional societies, and a variety of other stakeholders. Our vision for the future includes more state-level engagement, as that's where many education decisions are made.'

STEM EDUCATION COALITION
Science Technology Engineering Mathematics

www.stemedcoalition.org

Why do you think it's important for a broad range of people to join the STEM Education Coalition and what opportunities do you offer your members?

The diversity of our members is critical to our effectiveness. Each of our members brings a unique perspective on why STEM education is important to them and this has helped us to develop a more nuanced view of the policy landscape. Our members receive regular policy updates from our team, participate in meetings and briefings, and are key in shaping our policy agenda.

Why do you believe STEM education is important for the future of the U.S. economy and how are you working to raise awareness about the importance of supporting STEM education?

STEM jobs are growing faster than any other sector and our economy is only becoming more reliant on technology. Skilled workers who have the ability to thrive in a 21st century setting will be essential if the U.S. is to remain the global leader in this sector. Furthermore, STEM education and high-paying STEM jobs have the promise of being a great equaliser when it comes to gender and race pay gaps.

We regularly engage with decisionmakers in Washington D.C. and on the state-level to discuss the importance of STEM education with them. We also have a robust social media presence, which we use not only to discuss policy, but innovative learning happening around the country.

How are you working to expand capacity and diversity in STEM education and the STEM workforce of the future?

The Coalition views expanding the capacity and diversity of the STEM pipeline as an essential component of developing a 21st century workforce. We have supported legislation to promote underserved groups joining the pipeline. We work to incorporate

‘State and local education policymakers are trying to make innovative plans for the future, but it’s hard to plan when you’re unsure if your plans will be funded. Underserved areas could be hit the hardest.’

a variety of proven strategies, like mentorship opportunities, informal and out-of-school learning, hands-on activities, and advanced coursework, into STEM legislation to ensure high-quality STEM education is accessible to as many students as possible.

How are you working to influence policy and advocate for policies to improve STEM education? What current legislation are you most interested in supporting?

The STEM Education Coalition engages in a wide variety of public and behind-the-scenes actions to influence policy. These activities include regular meetings with key policymakers, hosting informational briefings for Capitol Hill staff, providing technical assistance for state-level advocates, tracking and monitoring legislation, and engaging with partner organisations.

We’re currently focused on making sure that any reauthorisation of the, ‘Carl D. Perkins Career and Technical Education (CTE) Act,’ includes provisions that foster partnerships and collaboration between CTE and STEM courses. We are also actively involved in the implementation of the, ‘Every Student Succeeds Act,’ on the state-level and within the federal Department of Education.

Tell us about your informal education state advocacy toolkit?

The toolkit was developed through a partnership with the Afterschool Alliance, a member of our Leadership Council. We hope that informal education advocates will use the toolkit to engage with state and local policymakers at a deeper level about the importance of out-of-school-time for STEM learning.

What are your views on the current uncertainties in funding for STEM education in the U.S. and the potential impact for the future?

The current budgetary uncertainties have put state and local education policymakers in a tough position. We believe that Title II and Title IVA of the, ‘Every Student Succeeds Act,’ should be funded as highly as possible within the congressionally authorised levels so states can continue to envision and implement a wide-variety of innovative STEM learning programs. Without these programs, states aren’t likely to have the ability to fund high-quality STEM learning at a sustainable level for the long term.

Finally, what do you see as the biggest challenge facing educators in STEM subjects over the next decade?

STEM must be embraced as a national priority and it’s unfortunately not on that level yet. On the K-12 level of primary and secondary education, we must embrace the emerging trends and best practices in learning. The nation must raise achievement in the STEM fields for all K-12 students both inside and outside the classroom, all across the country and in every community.

SUPPORTING CHILDREN WITH CHALLENGING BEHAVIOURS

Children with disruptive behaviours require intensive support in school. **Dr Andy Frey,** professor at the University of Louisville, has been developing and evaluating interventions that could help these children to begin their school years positively and successfully. The First Step Next and homeBase intervention programs involve a collaboration between parents and teachers to support children with problematic behavioural patterns achieve their potential.

Teaching Children with Challenging Behaviour

Challenging behaviour generally refers to a broad range of issues that children can present with in school, including disruptiveness, aggression, self-harm, difficulty communicating with others, or other disruptive tendencies. Some students with behavioural problems are affected by mental health conditions such as Attention Deficit Hyperactivity Disorder (ADHD), Oppositional Defiant Disorder, anxiety problems, or initial signs of Autism.

For children with challenging behavioural patterns, learning within school environments can be a difficult and problematic experience. It is hence important for teachers and other education specialists to take the needs of these children into consideration, implementing support programs and initiatives to help them achieve better results and develop a positive attitude towards academic environments.

This is often particularly useful for children in pre-school and primary school, when they are starting to develop their first attitudes towards life and academic environments. Early interventions can help to reduce the risks of these students taking destructive pathways or developing severe psychiatric disorders later in life, while also reducing potentially stressful situations for their school teachers and peers.

Dr Andy Frey has worked as a school social worker, behavioural coach, and mental health consultant for over two decades, trying to devise interventions that could help children with challenging behaviours to perform better in school. In recent years, he focused on developing and evaluating two interventions called First Step Next and homeBase, rooted in the idea that efforts to improve children's challenging behaviour should be collaborative – with behavioural coaches, teachers and parents working together towards positive change.

'My work aims to help young students with challenging behaviours get off to the best start possible in school,' says Dr Frey. 'This is done by developing and evaluating interventions that focus not only on working with young children directly, but also by working with parents and teachers – who control the environments that are so influential in shaping student behaviour. We also investigate methods to help peers support the disruptive students.'

First Step to Success Early Intervention Program

The First Step to Success program is a collaborative home-school intervention that lasts approximately 3 months, aimed at teaching young children with challenging behaviour the skills that could encourage their academic success.

‘My work aims to help young students with challenging behaviours get off to the best start possible in school.’

Dr Hill Walker of the University of Oregon first introduced this intervention through a model development grant from the US Office of Special Education that ran from 1992 to 1996. The original version of the First Step program is made up of four main components. Firstly, children are offered one-to-one sessions with a behavioural coach, who trains them in skills associated with school success. They are meanwhile provided with ongoing opportunities and feedback, aimed at facilitating their mastery of these skills in both classroom and playground contexts.

The third component of the intervention involves regular communication with the family, so that caregivers can encourage the good job the child is doing at school. Finally, there is a home component, for which parents are taught to support their children’s success in school within their household. The behavioural coach initiates the student’s acquisition of skills, encouraging his or her success in school, and is then gradually replaced in this work by the student’s teacher, who is still however supported by the coach throughout the three-month period.

Thus, the program was designed to provide substantial support upon initial implementation, then gradually become less intensive, reaching completion once the student’s academic and social performance improves. Several research studies assessed the effectiveness of the First Step intervention in small and large trials, finding that it was consistently successful in improving children’s school behaviour and performance.

The program has been applied successfully with approximately 2,000 students having challenging behaviour in pre-school and primary grades. It has also been translated into Spanish and adopted in schools in the US, Canada, Australia, New Zealand, Holland, Norway, and Turkey.

The First Step Program Revisited

After its initial implementations, First Step has undergone a number of different adaptations and innovations. Over the past few years, Dr Frey and his colleagues, including Dr Hill Walker and other original authors, revisited the First Step intervention, improving some of its aspects so as to be easier to implement by school personnel.

In their feedback, parents and teachers who had participated in the intervention said they felt it required a lot of time and effort, while coaches felt they needed more information about students’ behavioural characteristics and skills, in order to tailor the intervention to their individual needs. This and other feedback was used by Dr Walker and his colleagues to update the program over a one-year period and make it easier to implement.

They preserved the core elements of the original First Step program, including direct instruction in school success skills, group and individual contingencies, peer and home support, reward activities, and positive feedback for good behaviour. Many of the original procedures were also left the same, while some were either revisited or only slightly updated. Overall, First Step Next, the updated version of the original intervention, was designed to be effective, less complex and easier to implement.

First Step Next can be applied to students in pre-kindergarten (4 years old) through grade 2 (age 7–8), while the original program covered grades K-3 (age 8–9 years) and relied on a separate preschool version for children in earlier developmental stages. The new version of the program also includes a series of pre-implementation screening procedures, such as an assessment of the students’ relevant characteristics and of their classroom climate, which can help to tailor the program to each child’s individual needs.

First Step Next also features new competencies to guide the intervention, called the Super Student Skills. These are social-emotional and academic enabling skills that should be enhanced by the intervention, including things such as 'follow directions', 'ask for attention the right way', 'do your best work', and more. It also features new tasks, games and home-school activities, which should re-enforce the skills that the children are trying to acquire.

Some of the parent involvement activities included in the original First Step intervention were retained, while the home component, an initiative that consisted of six home visits by the behavioural coach, was eliminated from First Step Next, and developed by Dr Frey and his colleagues as a stand-alone intervention. Parents are hence no longer asked to teach the Super Student Skills to their children at home, a task that becomes the sole responsibility of the coach and teachers at school.

Parents participate in the revisited version of the program through phone calls or meetings with the coach and daily 'check-in' notes, as well as rewarding children for positive behaviour and supporting them in their school progress.

HomeBase: Involving Parents in Children's Behaviour at School

homeBase started off as part of the First Step program, but it is now treated as a separate intervention that could supplement either First Step Next or other school-based interventions. homeBase is an entirely family-based intervention designed to support parents in trying to improve the challenging behaviour of their children. It includes up to six, hour-long sessions with a behavioural coach intended to increase parents' motivation and improve their parenting practices.

During home visits by behavioural coaches, parents are encouraged to gain awareness of their parenting practices and re-visit some of them, in order to foster positive change in their children that could also improve their overall behaviour in school. Parents are asked to replicate some of the principles of parenting that encourage positive behaviour central to good performance in school. This includes establishing clear expectations for their children in terms of behaviour and school performance, as well as defining the consequences or rewards of negative versus positive behaviour. An innovative aspect of the new standalone homeBase intervention is that the 60-minute sessions with parents are developed around a counselling approach called Motivational Interviewing.

Motivational Interviewing (MI) is a particular style of communication centred around the language of change, designed to strengthen personal motivation and commitment towards a particular goal. MI does this by exploring a person's reasons for wanting to change with support, compassion and acceptance. The main idea behind this practice is that talking about change and arguing for it tend to accelerate the process, while arguing against it tends to prevent change from happening.

So far, assessment studies have suggested that the process Dr Frey and colleagues have developed, the Motivational Interviewing Training and Assessment System (MITAS) can be a very effective method in preparing behavioural coaches to use MI skilfully with parents, ultimately leading to tangible improvements in parent and child behaviour.

The Future of homeBase and First Step Next

Dr Frey and his colleagues are currently assessing the effectiveness of the First Step Next and homeBase interventions, as well as the perceptions of participating teachers and parents. They are carrying out research to evaluate the effectiveness of these two interventions when delivered alone and in combination, which should help us to understand the most effective strategies to tackle students' behavioural problems in school.

Results that have been collected so far have been promising, with teachers reporting improvements in students who participated in First Step Next and homeBase intervention programs compared to others who didn't. Overall, First Step Next and homeBase resulted in greater academic engagement compared to students who did not receive either intervention, and those who received the First Step Next and homeBase interventions have experienced the greatest improvements. Dr Frey and his team are now working on a National Institute of Child Health and Human Development application that would allow them to conduct a further efficacy trial for the homeBase intervention with parents of preschool children.

In the future, they also plan to develop a universal First Step Next variation, called First Step Next – For All, that would allow for a similarly structured intervention that is applied with all students in a classroom setting simultaneously in hopes of preventing challenging behaviour from occurring and developing into a characteristic behaviour pattern.

Dr Frey says, 'we will also continue promoting our Motivational Interviewing Training and Assessment System, as we believe MI is a promising skill set to address a wide range of challenges in implementing effective evidence-based practices in the context of school-based intervention research and practice.'

Meet the researcher

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Dr Andy Frey is a Professor at the University of Louisville, Kent School of Social Work. After completing a BA at Rollins College in Florida, a Masters in Social Work at the University of Michigan, and a PhD at the University of Denver in Colorado, Dr Frey has worked as a social worker, behavioural coach, and consultant in a number of academic settings. He has worked with children for over 25 years and has been a mental health consultant for Jefferson County Public Schools' early childhood program for the past 16 years. Dr Frey's research and teaching has focused on school-based mental health and social work services, such as the First Step Next intervention, home-based approaches, and motivational interviewing within school settings. His work is currently aimed at comparing the effectiveness and impact of interventions for children with disruptive behaviour. Over the course of his career, Dr Frey has received a number of awards, including the Gary Lee Shaffer Award (2010) from the School Social Work Association of America, the Outstanding Scholarship, Research, and Creative Activity in Social Sciences Award (2015) from the University of Louisville and the School of Social Work Scholar Award from the University of Denver (2015).

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FIRST STEP Next

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BEST IN CLASS: IMPROVING INTERACTIONS BETWEEN TEACHERS AND STUDENTS

Young students who exhibit problematic behaviours in school often fail to fully benefit from their educational experiences and can have adjustment problems later in life. **Dr Maureen Conroy** at the University of Florida and **Dr Kevin Sutherland** at Virginia Commonwealth University have been developing a classroom-based intervention model called BEST in CLASS, designed to improve how teachers and young children with chronic behavioural problems interact with each other.

Chronic Problematic Behaviour in Early Childhood

The number of children under five who present challenging behaviours that could interfere with their social or emotional development is on the rise. Studies suggest that around 14–30% of preschool children exhibit significantly problematic behaviour and that these rates tend to be higher for children living in poverty.

The term 'problematic behaviour' generally refers to a wide range of issues, including difficulties in interacting with others, disruptiveness, heightened aggression, or other anti-social tendencies. In very young children, these could be the initial signs of emotional and behavioural disorders, a series of conditions in which a child's behaviour and emotions are greatly different from typically accepted norms, to the point of negatively affecting his or her performance at school or in other life situations.

In some cases, children who display challenging behaviours from a very young age can later be diagnosed with conditions such as conduct disorder, oppositional defiant disorder, Attention Deficit and Hyperactivity Disorder (ADHD), or anxiety disorders.

An early onset of behavioural issues in young children has also been found to predict other problems, such as drug abuse, juvenile delinquency, violence, and early school dropout. For children with problematic behaviours, learning and feeling at ease within school environments can be particularly challenging.

In time, adverse experiences in early school years could lead these children to develop an unpleasant relationship with classroom environments, accentuating their behavioural issues further. Teaching these children and helping them to modify their problematic behaviour can be a very difficult task and teachers might need to resort to more personalised instructional methods, tailored around their needs.

A Need for Early Interventions

Research has found that if a child's behavioural problems are not addressed at a young age they tend to increase over time, with the child needing more intensive support in the future. Evidence suggests that problematic behaviour could often be altered by effective early intervention programs designed for young children who are encountering difficulties as they are first entering learning environments.

Over the past few decades, researchers have tried to devise models that could be applied in early education settings, in order to address children's behavioural problems sooner and try to prevent these from evolving into more serious issues.

Dr Conroy and Dr Sutherland have carried out extensive research into social and behavioural disorders in children, trying to devise interventions that could help affected children to develop an enduring positive

‘BEST in CLASS is a classroom-based tier-two model that trains and coaches teachers to improve their interactions with young children and students who exhibit chronic problem behaviour.’

relationship with their teachers in learning environments. Together, the two researchers have developed BEST in CLASS, a classroom-based tier-two early intervention program designed to improve chronic problematic behaviours in children who are at risk of developing emotional and behavioural disorders.

BEST in CLASS Intervention Program

The BEST in CLASS intervention program was developed by Dr Conroy and Dr Sutherland working with other researchers from their respective universities. The project, funded by the National Center for Education Research, the National Center for Special Education Research and the Institute of Education Sciences of the US Department of Education, is aimed at addressing the needs of young children who present persistent and severe problematic behaviours within early learning environments.

Drs Sutherland and Conroy describe that, ‘BEST in CLASS is a classroom-based tier-two model that trains and coaches teachers to improve their interactions with young children and students who exhibit chronic problem behaviours.’ They explain that, ‘teachers are trained and coached to implement evidence-based practices with these children as well as strategies for engaging families.’

The intervention has two main components, one being the content used to train teachers on how to encourage appropriate behaviours and social skills in the classroom, and the other focused on establishing a home-school partnership that could help improve the children’s problematic behaviour.

The first component of the BEST in CLASS intervention is aimed at coaching teachers of students from preschool to Grade 3 (aged 3–8 years old) on the use of evidence-based instructional practices that could support children with challenging behaviours in their learning, preventing their behaviour from evolving into further issues in the future.

While most teachers may be already using some of these methods, BEST in CLASS trains and coaches’ teachers to increase their high-quality use of these practices, in order to successfully instil the social and behavioural skills necessary for success in school to young children who might need it the most.

Coaching Teachers to Interact with Challenging Young Children

The coaching model used by BEST in CLASS was developed by Dr Conroy and Dr Sutherland, based on the findings of prior special education research. The model is based on the notion that high-quality learning environments for children with problematic behaviour should be tailored around their individual needs. It supports teachers to use the evidence-based practices with specific students in their classroom who have chronic problem behaviour.

Teachers participating in the intervention receive a BEST in CLASS teacher manual and attend a one-day workshop introducing them to seven learning modules. During this workshop, the teachers are asked to complete a series of practical activities, view video examples of how to implement BEST in CLASS practices in their classroom, and participate in role-play scenarios with their coaches.

Subsequently, the teachers are coached individually for 14 weeks by a trained coach, who provides guidance and teaches them how to implement practices that could improve their students' problematic behaviour. The BEST in CLASS training and coaching model focuses on practices such as rules, pre-correction, behaviour specific praise, opportunities to respond, corrective feedback, and instructive feedback.

The teachers collaborate with their coaches throughout the training period, setting goals for the teachers' use of the practices in their classrooms and working together towards meeting these goals, by implementing the program's teaching practices in ways that might be more beneficial for their children. Teachers are then asked to apply what they discussed during the coaching sessions to their interactions with students who have been found to display persistent behavioural problems. After helping the teachers to devise a plan of action for specific children, the coach conducts weekly observation and feedback sessions as well as checking-in with them on a regular basis via e-mail or phone.

During weekly coaching meetings teachers are encouraged to reflect on their use of BEST in CLASS practices, communicating any relevant feedback or insights to the coach through a weekly self-reflection form. During the 14 weeks of coaching, coaches observe the teachers in a classroom situation and then meet with them to reflect on whether the goals they had set together have been met.

The families of the young students who present challenging behaviours are also involved in the program through the establishment of a stronger home-school partnership, and teachers are supported by coaches to encourage parents or caregivers to communicate with their children's teachers on a regular basis.

Assessing the Effects of BEST in CLASS

Dr Conroy and Dr Sutherland have carried out a series of studies funded by the Institute of Education Sciences, to determine the effects of their BEST in CLASS intervention on the behavioural, social, emotional, and pre-academic outcomes of pre-school children at high risk of developing emotional and behavioural disorders.

These studies assessed the effects of BEST in CLASS by comparing two samples of teachers, one who participated in the program and one who did not. Among other things, these studies assessed how teachers used the relevant instructional practices and whether they felt more confident in delivering them after receiving coaching.

The BEST in CLASS intervention was found to have a positive impact on the teacher's sense of self-efficacy, with those who took part in the intervention using instructional practices more effectively and confidently than those who didn't.

After receiving coaching, the teachers demonstrated more competence in delivering instructional practices and felt they were more able to meet the individual needs of their students. Other important aspects that were examined include the general atmosphere in the classroom before and after the intervention, as well as the quality of interactions and relationships between the children and their teachers.

The researchers found that BEST in CLASS had an overall positive impact on the classroom atmosphere, increasing engagement of children in the treatment group and reducing their problematic behaviour. Moreover, the program also appeared successful in improving interactions between teachers and children who had persistently displayed challenging behaviour, increasing the number of positive exchanges and decreasing negative ones.

Tackling Behavioural Difficulties from a Younger Age

The introduction of high-quality early childhood intervention programs is of great importance, particularly for younger children who are more at risk of developing emotional and behavioural disorders. The first years of life tend to be the best time to address particularly challenging behaviours and many interventions in early learning environments were found to be effective in improving children's problematic behaviours.

Programs such as BEST in CLASS could be of great assistance to pre-school and elementary teachers, providing important support and guidance on how to best address any chronic behavioural problems presented in their classroom. In their research assessing the effects of the intervention, Dr Conroy and Dr Sutherland observed that the teachers' increased and higher quality delivery of instructional practices can be effective in improving young children's behaviour in the classroom.

The BEST in CLASS intervention program also appeared to prompt a cascade of positive effects on teacher-child interactions, relationships and classroom atmosphere, that was ultimately beneficial for both the children and their teachers. In future, the researchers aim to assess whether teachers who take part in the intervention continue to effectively deliver the BEST in CLASS instructional practices in the years after the program is complete.

Despite indications that support its effectiveness as an intervention to address problematic behaviours at early stages of life, the BEST in CLASS intervention might be difficult to be delivered in all educational settings given its use of coaches to support teachers' use of the practices. The current program requires teachers to meet up with coaches on a weekly basis, so some schools might not have the resources to completely implement the coaching aspect of the model.

The researchers are hence working on the development of a more efficient model, including a web-based adaptation that could reach a greater number of teachers and would not require as many resources as the face-to-face program.

In addition, Drs Conroy and Sutherland describe how, 'we're also currently adapting BEST in CLASS preschool for elementary school teachers, students and families and hope to test this model in a large randomised controlled trial.'

Meet the researchers

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Dr Conroy is the Anita Zucker Endowed Professor, Professor of Special Education and Early Childhood Studies, and the co-director of the Anita Zucker Center for Excellence in Early Childhood Studies at the University of Florida. She holds an MEd and a PhD in Special Education from Vanderbilt University. Dr Conroy has carried out extensive early intervention research on children with social behavioural disabilities, or those at risk of developing them. She is a regular speaker at International conferences on topics related to early childhood and has received countless grants and awards for her work. Dr Conroy has published over 100 articles and chapters in the fields of autism, early intervention, and behavioural disorders.

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THE HIGH COST OF GRADE RETENTION

Holding students back a year sets them up for dropping out of school. Young adults who drop out are at higher risk for social and health problems later in life. **Professors Jan N. Hughes** and **Stephen G. West** of Texas A&M University and Arizona State University, respectively, have completed a 14-year longitudinal study of grade retention, providing the strongest evidence to date that retention in the elementary grades impairs students' odds of completing high school.

The Burden of Dropping Out

Every year, hundreds of thousands of children in the United States drop out of high school without obtaining a diploma. Dropping out of school is a major concern for educators and policymakers as it is detrimental, not only to the child, but to society at large. Adults without high school diplomas or general education development certificates (GED) frequently have lower paying jobs and are more likely to be unemployed, on government assistance, or in prison. Even when incomes are equal, high school dropouts are often in worse health than their peers with diplomas.

Dr Jan Hughes, an expert in childhood development and educational attainment and Dr Stephen West, a prominent specialist in statistical methods applied to psychological and social data, have engaged in a 14-year longitudinal study to describe factors that contribute to high school dropout.

The key factor that Drs Hughes and West have chosen to focus on in their work is the practice of grade retention or holding underperforming students back a year in the hopes of bolstering their performance and ensuring they are prepared for the more advanced materials they will encounter in the next grade up. While the practice is well intentioned, it has attracted criticism from many educational experts, as retained students often continue to struggle academically and drop out of school at a higher rate than students who are promoted.

Grade retention is a common and expensive educational intervention. In the 2015-16 academic year, nearly 38,000 students attending Texas public schools were retained in grade – they stayed in the same grade for two consecutive years. The cost of that extra year of schooling, based on the state average expenditure per student, was over $384M. However, the highest cost of grade retention may be its negative impact on high school completion.

Research on the effects of grade retention on educational attainment has been on-going for decades; yet strong empirical evidence of the effects of grade retention – especially on long-term educational attainment – has been lacking. The primary problem in prior research is a failure to provide unambiguous evidence that grade retention is the *cause* of subsequent academic performance, rather than merely a marker of pre-existing differences between students who are subsequently retained and those who are promoted.

Students who are retained in grade and those who are promoted differ on a large number of factors *prior* to retention – most notably on academic performance but also on a host of other variables. Thus, differences between retained and promoted students in educational attainment at some point in the future may be due to these pre-existing differences and not to retention. Dr Hughes explains, 'the factors that increase a student's risk of being retained in grade, such as low achievement, family poverty, low cognitive competence and poor learning-related skills, also increase their risk of subsequent low achievement and dropping out of school, thus confounding the causal interpretation of grade retention effects.'

Taking a Long View on Early Education

Due to these confounding factors, in 2001, when Drs Hughes and West first embarked upon their study of the effects of grade retention, very little was known about the long-term effects of the practice, despite its common use in the United States. Understandably no parent would agree to place their child in a controlled study where children are randomly assigned to repeat a grade or to be promoted.

‘Given the harm to students and costs to society associated with failure to obtain a high school diploma or GED, alternatives to grade retention are needed for students who struggle to meet minimum grade level competencies in the elementary grades.’

Absent such a controlled experiment, the best approach would be to conduct a longitudinal study on a large group of first grade students, none of whom had previously been retained in first grade, and to follow these children for at least 14 years, giving students 14 years to complete grade 12 or earn a GED.

Prior to any student being retained, data covering a wide range of variables that are associated with both grade retention and future educational attainment would be obtained, and the study would use cutting-edge statistical methods to control for potential confounding variables, such as low academic achievement and socioeconomic status, thereby isolating the effects of grade retention alone.

Dr Hughes explains, ‘prospective, longitudinal studies of students over the entire course of their public schooling are extremely rare. Such studies are very expensive, due to the cost of tracking students who often move out of their beginning school district and conducting annual assessments. Obtaining continuous funding for 15 years is also difficult. Yet longitudinal studies are critical to understanding the short-term and long-term impacts of students’ experiences at school.’ With funding awarded to Dr Hughes from the National Institute of Child Health and Human Development (NICHD) for 15 years, Drs Hughes and West set out to do just that. The pair recruited 784 academically at-risk first grade students who were enrolled in one of three Texas school districts in the fall of 2001 or 2002. Collectively, the population of these schools was demographically similar to that of the first-grade population in Texas. Participants were selected on the basis of having scored below average on a test of literacy at the end of kindergarten and having parent consent for study participation.

Prior to any student being retained, they obtained extensive data on their academic, behavioural and social-emotional functioning from teachers, parents, and classmates through questionnaires and school records, as well as from direct testing and interviewing of the children. Importantly the team went to great lengths to follow all students for 14 years, using student identification numbers to locate families that moved to other school districts both inside and outside Texas. They tracked students’ academic progress and conducted annual assessments of students’ academic achievement as well as their social and behavioural adjustment.

At the end of the first 5 years of the study, elementary grade retention status was available for 734 students (93.6% of the original sample), a very low attrition rate over 5 years given the high mobility of the sample. Of these students, 256 were retained during grades 1-5 and 478 were continuously promoted. At the end of 14 years, 477 had graduated, whereas 110 had dropped out, 21 had obtained their GED, and 126 had a graduation status of unknown.

The team also amassed a wealth of data on the students’ academic achievement, educational motivation, psychological adjustment, and relationships with peers and teachers. They were then able to use this information to draw broader conclusions about how grade retention affects students’ academic achievement and school adjustment at various developmental stages.

Systemic Failures and Hope for the Future

Common belief has held that grade retention negatively affects the well-being of students, but Drs Hughes and West reached a more nuanced conclusion. Their yearly assessments illustrated that through grade 9 – typically age 14-15 for students promoted in the elementary grades and 15-16 for students retained in the elementary grades – students who had been held back a year in the elementary grades were just as well adjusted as their matched but promoted students. Retention had not harmed children’s peer relationship, academic achievement, conduct, or educational motivation.

However, despite the appearance of no effects of early grade retention through grade 9, students who had been retained a grade during grades 1-5 were 2.67 times more likely than their continuously promoted peers to drop out rather than

complete high school.
Because the study effectively removed differences between retained and promoted students on 65 relevant variables measured at baseline, prior to any student being retained, the study provides the strongest evidence to date that early grade retention is a cause of dropping out of school and not merely a correlate of baseline differences in retained and promoted students. Early grade retention did not have an effect on dropping out of school versus obtaining a GED.

One of the most concerning results is that retention has disproportionately negative effects on Black and Hispanic female students. Dr Hughes describes that, 'not only are Black and Hispanic youth more likely to experience grade retention than White youth, retention is particularly harmful to minority girls, especially Black girls, relative to White girls. Thus, retention contributes to ethnic disparities in educational attainment, especially of minority girls.'

While the team's studies indicated that retention during grades 1 through 5 had little effect up to grade 9, the transition to high school, occurring at grade 9, appears to be a critical juncture for dropping out of school. The transition to high school is difficult for many adolescents, with sharply increased academic demands, but the transition is particularly perilous for students who have previously been held back during their primary education.

Dr Hughes suggests that, 'many grade 9 students struggle to earn the credits necessary to advance to grade 10.' Yet previously retained students, in contrast to their matched but promoted peers, typically turn 16 (not 15) during or shortly after grade 9. At age 16, under certain conditions, Texas youth can work full time or leave school to pursue a GED. With 4 or 5 years till graduation and that not a certain outcome, many retained students choose to leave school when 16.

Throughout, the 14 years of the study, Dr Hughes and her team have found that a supportive relationship with teachers increases students' academic engagement and achievement. Dr Hughes summarises, 'these results suggest that policies and practices that increase academic and social supports at the critical 9th grade year could increase school graduation rates. Several comprehensive school reform efforts that focus on increased supports for entering freshmen have shown promise in increasing rates of promotion to grade 10 and graduation.' These programs focus on smaller, more personalised learning communities for freshman students and pre-emptive support for students at risk of failing classes. They also include a more targeted curriculum for helping students catch up on course credits. Professional development for teachers that provides training for building supportive student relationships and adapting teaching plans for the needs of students in a given course are also recommended.

Dr Hughes notes, 'given the harm to students and costs to society associated with failure to obtain a high school diploma, alternatives to grade retention are needed for students who struggle to meet minimum grade level competencies in the elementary grades.' Promising are multi-tiered models of intervention, which involve a graduated series of evidence-based instruction and intervention to students who begin to fall below grade-level expectations. These intervention models include (a) universal screening for academic or social-behavioural difficulties; (b) the provision of early and intensive evidence-based interventions for students encountering difficulties; and (c) frequent progress monitoring and evaluation of interventions.

The Next Phase

Dr Hughes hopes that the data collected from this longitudinal study of an ethnically diverse sample of children from grade 1 for 14 years will live on through the work of other researchers. As such, it has been made publicly available through the National Institute of Child Health and Human Development's website. The title of the NICHD study found at https://dash.nichd.nih.gov/study/14412 is, 'The Impact of Grade Retention: A Developmental Approach.' Statisticians and social scientists are invited to comb through the data, analysing it from new angles for hidden insights, relating it to their own work.

Dr Hughes describes how, 'all the data, measures, and study protocols are archived here, where other researchers can answer questions we did not address about factors that impact children's development across the public-school years.'

Meet the researchers

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Stephen G. West is Professor of Psychology at Arizona State University and Gast Professor of Methods and Evaluation at Freie Universität Berlin. He has received three lifetime contribution awards from learned societies, as well as the Alexander von Humboldt Foundation (Germany) senior Forschungspreis (research prize) for lifetime contributions to quantitative research methods. He has served as President of Division 5 of the American Psychological Association and President of the Society for Multivariate Experimental Psychology. He has also received awards for graduate teaching and mentoring. During his career he has served as editor of the Journal of Personality, Multivariate Behavioral Research and as associate editor or editorial board member of these and several other journals in the behavioral sciences. His work has been in the area of quantitative research methods with applications in education, health, mental health and personality.

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UNDERGRADUATE RESEARCH

IMPROVING UNDERGRADUATE STUDENTS' ACCESS TO RESEARCH EXPERIENCES

Without question, the world needs more knowledgeable and skilled-up STEM graduates. These students will go onto solve some of the world's greatest challenges. Not only that, they will be needed to fill the millions of STEM-related jobs available in the future. The US Department of Commerce estimates that STEM jobs will have grown by 17% between 2008 and 2018. By contrast, there will have been only 9.8% growth in non-STEM related fields. That trajectory will only continue.

To prepare and equip undergraduate students to meet the challenges that lie ahead of them, many researchers, educators and institutions recognise the need to provide them with authentic learning experiences much earlier in the piece. This involves giving undergraduates an opportunity to engage in hands-on and real-world activities, and in some cases, to conduct research in which they solve real-world problems.

In this section of the edition, we feature several amazing initiatives that are promoting career readiness for undergraduate college students. For instance, a team of researchers at Auburn University has developed a set of educational modules for first year engineering students to help enhance the freshman learning experience and alter perspectives about what it means to be an engineer. Amazingly, the team has focused their learning modules on the field of nanotechnology – something that a freshman would see as 'pie in the sky' sort of stuff. It's easy to see why such programs would enthuse students to pursue careers in STEM. They also equip them with the relevant practical skills to help them on their way.

Another challenge relates to when undergraduate research opportunities are offered. In many cases, they are not conducted within normal class time – many occur after hours or during summer breaks, a time when some students are compelled to seek employment. This limits student access to undergraduate research opportunities. Dr Kelly McDonald and Dr Thomas Landerholm of California State University want to ensure, however, that research becomes a more intrinsic part of undergraduate studies, and that students are given real-world challenges to research. Specifically, their so-called 'SIRIUS' project entails studying the American River, which runs through the campus and has been listed as impaired since the 1970s.

Keeping in step with the theme of providing undergraduate students with authentic research opportunities, we will next look at the work of Dr Andrea Holmes and Dr Christina Wilson of Doane University in Crete, Nebraska. They are partnering with the Karlsruhe Institute of Technology in Karlsruhe, Germany, to provide students with unparalleled experiences in nanotechnology research for biomedical applications. In addition to providing these opportunities, the program covers travel and expenses for undergraduates to perform collaborative research abroad.

We will then introduce two initiatives that not only offer students invaluable research experience, but also promote diversity in STEM education. For example, a program implemented by Dr Justyna Widera-Kalinowska and her colleagues aims to get students involved in nanomaterials research for environmental applications early in their careers. In addition, the program has a focus on recruiting, and providing financial support to students who are typically underrepresented in STEM fields.

Offering financial assistance to students is indeed a practical way to encourage diversity and support students on the paths to a STEM career. Another example of the effectiveness of this strategy is the so-called, 'Scholarships-Creating Opportunities for Applying Mathematics Program', or S-COAM, developed by Drs Yu-Ju Kuo and Frederick Adkins at Indiana University of Pennsylvania. In addition to offering research and internship opportunities to students, the program also provides financial aid, empowering students to pursue advanced mathematics courses. It also promotes college retention and sets students up for life-long learning.

STUDENTS USING NANOTECHNOLOGY TO SOLVE THE WORLD'S GREATEST CHALLENGES

The field of engineering is central to innovations across science and technology, yet many college students show a lack of interest in pursuing engineering careers. Educators at Auburn University are developing innovative educational modules that engage students in solving humanity's biggest challenges using cutting-edge engineering techniques, cultivating enthusiasm for engineering careers along the way.

From climate change to clean water, and from life-saving pharmaceuticals to international security, many of the present challenges facing humanity can only be solved through science and engineering. As technology has advanced over the past century, the field of engineering has found itself at the crux of modern science, touching every scientific discipline from biology to astrophysics.

Through the creation of advanced materials and incredible leaps in computing, engineers shape the human experience in countless profound ways. Our future will depend on engineering innovations in every corner of science and technology. Despite the need for diverse and talented engineers, first-year college students report low interest in pursuing engineering as a major, and many of those that do take engineering courses in their first year will not continue on to achieve engineering degrees.

Thus, while the world relies on engineers to solve major challenges, one of the biggest challenges within the field is increasing the number of young engineers. Further, the male-dominated field stands to benefit from the unique perspectives offered by female engineers and under-represented minorities, yet retaining these demographics has proven difficult in standard educational models.

Now, a team of researchers at Auburn University have developed a set of educational modules for first year engineering students to help enhance the freshman learning experience and alter perspectives about what it means to be an engineer. Drs Edward Davis, Virginia Davis, and Joni Lakin are determined to reshape the way students engage with engineering at the beginning of their careers, in the hope of retaining broader diversity and student involvement.

Dr Edward Davis describes the team's drive: 'The future will be shaped by the things engineers develop – new power sources, better and cheaper medicines, new diagnostic equipment to catch diseases earlier, new ways to provide clean water, enhanced virtual reality, and a myriad of other technologies are essential to our health, happiness and safety. Training more engineers is critical to the future of our society.'

The Future of Engineering

Nanotechnology, the manipulation of materials at the molecular scale, is poised to become a critical aspect of the solutions to many of the current problems humanity faces. 'Our understanding of nanoscale phenomena is growing and nanotechnology enabled products are more and more prevalent,' says Dr Edward Davis. 'It is becoming clear that future engineers will deal with nano-enabled materials and technologies in their careers.'

However, many students just entering engineering view nanotechnology as the stuff of science fiction, and those that are interested

‘The future will be shaped by the things engineers develop – new power sources, better and cheaper medicines, new diagnostic equipment to catch diseases earlier, new ways to provide clean water, enhanced virtual reality, and a myriad of other technologies are essential to our health, happiness and safety’

in the field usually have to wait until graduate school if they wish to learn more about this promising branch of engineering. In 2014, the United States National Science Foundation identified nanotechnology as a critical area of engagement for young engineers, and started the Nanotechnology Undergraduate Education (NUE) in Engineering initiative, with the goal of funding innovative nanotechnology educational programs at the college level. The team at Auburn University secured NUE funding by proposing to develop six learning modules designed for introductory college engineering courses. A major goal of the team’s work is to bring the perception of nanotechnology from a novelty research specialty to a core component of standard engineering curricula.

In order to shape the topics of their learning modules, the team turned to the National Academy of Engineering’s list of Grand Challenges for Engineering – a collection of 14 goals for the 21st century that would dramatically improve human life, created by an international team of leading technological thinkers. The Challenges encompass broad and ambitious goals that touch many other areas of science, such as making solar energy economical, providing access to clean water, enhancing virtual reality, engineering better medicines, securing cyberspace, and improving urban infrastructure.

The Auburn team has identified ways that nanotechnology could be implemented in each of the Grand Challenges. For example, the challenge to develop carbon sequestration methods that would mitigate global climate change could be aided by nanostructures that capture carbon dioxide, while nano-engineered catalysts could help transform this carbon dioxide into useful materials. Students that participate in these modules are not only becoming literate in nanotechnology, they are also exposed to some of the key problems they will face in their careers as scientists and are encouraged to begin thinking about how they can use engineering to solve them.

Building Multifaceted Understanding

The modules are divided into three basic parts, which are designed to be adaptable to a wide range of curriculums, time constraints, and class sizes. First, students are introduced to a Grand Challenge, such as making solar energy economical. Here, they learn about the current technology used to address the Challenge – in this case traditional solar panels.

Second, students learn about potential nanotechnology solutions to the problem. For the solar energy example, this includes reduced manufacturing costs, improved light absorption, and more efficient conversion of light energy – solutions that could all be made possible through the development of advanced nanostructures. When taught at Auburn, this segment of the module often includes visits from guest speakers from industry, to help students appreciate that these concepts are being applied in the real world. This also gives them the opportunity to meet real engineers that they can relate to as people.

Third, students engage in activities that allow them to leverage their new knowledge of the Grand Challenge, while also actively learning engineering principles and skills. These include how to use common equipment, how to perform basic engineering calculations, and how to communicate their findings. In the solar energy module, students first explore the capacity and limitations of a basic store-bought solar panel, and then go on to create their own panel using nanoscale titanium dioxide and raspberry juice.

Comparing the results from these two activities gives students the opportunity to practice discussing science with their peers, thus solidifying their knowledge and understanding from the earlier lessons. To conclude the module, students work in small teams to write a comprehensive lab report that incorporates learnings from each stage of the module and develops their scientific writing skills.

The team's initial pilot projects of the modules have shown great promise in classrooms at Auburn University. When compared to students who had followed the traditional curriculum, students that had received the 'Grand Challenges' modules were significantly more knowledgeable about nanotechnology, in both objective measures and self-reported understanding. Students who had completed the modules also showed much more confidence in their ability to complete a series of nano-related tasks, than students who had taken engineering courses from the same professor, but had followed the traditional curriculum. Further, students that had engaged with 'Grand Challenges' modules showed more interest in continuing engineering classes and had more positive attitudes toward engineering careers.

Increasing Inclusion by Tapping into Values

While the Auburn team's modules are designed to increase learning and engagement for any student, they are also aimed at increasing student retention, particularly among female students and under-represented populations. Research completed by the research team indicates that female students are more likely to want to pursue altruistic careers that benefit the greater good, such as medical careers, rather than status careers that primarily benefit the individual, such as careers in finance. Traditionally, engineering has been thought of as a status career, largely due to an underappreciation for the broad reach that engineering has across science and technology.

Through grounding in the Grand Challenges, the team hopes to educate students in the altruistic roles that engineers play in society. They want to motivate female students (and altruistically-minded male students) to pursue engineering by supporting the perception that engineering is a helping profession, just as much as public health and education. 'One facet of the work focuses on understanding the motivations of students in choosing an engineering career, student perceptions and misconceptions of what engineering is and what engineers do, and how students view their future roles in society,' Dr Edward Davis notes.

As part of this aim, the team uses surveys at the beginning and end of the semester to track how students' values and perceptions of engineering and nanotechnology change through their participation in the nanotechnology Grand Challenge modules. So far, they have found that participation in the modules increases all students' perception of engineering as a potential altruistic career path, while students with instructors that did not participate in the modules showed no change in career perceptions.

The team also found that the modules that focus on human health and wellbeing, such as engineering better medicines, appeal most to female students, while modules such as personalised learning and enhanced virtual reality appealed most to under-represented minority students. They also discovered that nanotechnology itself carries a positive connotation across all student demographics, and appears to be an effective thread by which to connect modules across the varying Grand Challenges. While it is still too early to observe how participating in these modules affects the long-term retention of students from diverse groups, instructors that wish to resonate with a broad range of students can select modules that are likely to appeal to a range of demographics.

The Next Step in Engineering Education

Engineering students at Auburn University are already reaping the benefits of the nanotechnology Grand Challenges modules, and the research team plans to expand the teaching of these modules in introductory courses across the engineering college over the next year. They are developing additional modules based on Grand Challenges that students have expressed high interest in, and intend to keep refining the current modules for wider distribution outside of Auburn University, including making electronic resources widely available online.

Over the next few years, the team also hopes to extend the program to even younger students. 'Our goal over the coming years is to increase the number of schools and courses using these, and similar, modules,' says Dr Edward Davis. 'In addition, we are working to leverage our success at the college freshman level to develop programs that introduce the concepts to middle- and high-school students. The hope is that this effort will improve learning by these students and motivate them to consider engineering as a profession.'

Meet the researchers

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Dr Edward Davis earned his PhD in Chemical Engineering from the University of Akron in 1997, after completing an MSE in Chemical Engineering and BSE in Biomedical Engineering at Tulane University. He went on to spend his early career in the commercial plastics industry, holding positions at Shell Chemicals in Belgium and EVALCA in Houston, Texas. In 2007, he joined the faculty at Auburn University, where he has regularly taught courses across three different engineering departments. He currently serves as an Assistant Professor in the Department of Mechanical Engineering in the Materials Engineering Program.

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Dr Virginia Davis began her engineering education at Tulane University, where she earned both her BSE and MSE in Chemical Engineering. She spent 11 years at Shell Chemicals engaged in polymer research and development, before returning to academia to complete her PhD in Chemical and Biomolecular Engineering from Rice University in 2005. Upon graduation, she immediately joined the faculty at Auburn University, where she currently has an Alumni Professorship in the Department of Chemical Engineering. Among her many awards and recognitions are an NSF CAREER Award (2009), a Presidential Early Career Award for Scientists and Engineers (2010), and Auburn's Excellence in Faculty Outreach Award (2015).

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MAKING RESEARCHERS OF STEM UNDERGRADUATES

The Sustainable Interdisciplinary Research to Inspire Undergraduate Success (SIRIUS) Project provides STEM undergraduates with practical research experience to better prepare and encourage them in their STEM pursuits. **Dr Kelly McDonald** and **Dr Thomas Landerholm** of California State University, Sacramento, have discovered SIRIUS has had tangible benefits to students in cultivating skills and enthusiasm relating to scientific research.

A Growing Need

There have recently been urgent calls to increase the training of students for the 21st century workforce, and to increase the number and diversity of science, technology, engineering and mathematics (STEM) students. This is accompanied by a demand for science pedagogical reform. Scientific organisations and committees have called for science to be taught the way it is practised by professional scientists. They recommend that more elements of independence are fostered in students, such as autonomy and encouragement to enquire and discover. Students can be acclimatised to this through research-based experiences called Undergraduate Research Experiences (UREs).

At California State University, Sacramento (CSUS), a 2015 survey indicated that 91% of biology majors wanted to do undergraduate research. Unfortunately, only 3% per year had the opportunity to do this in a one-on-one or small group setting mentored by faculty. As pointed out by the Principle Investigators (PIs) of the project, Dr Kelly McDonald and Dr Thomas Landerholm of CSUS, a scarcity of resources means that there is often inequality in the distribution of the opportunities that are available.

Traditionally, UREs have not been facilitated as part of normal class time – many must occur after hours or during summer breaks, a time when some students are compelled to seek employment. This creates a restriction on the diversity of the STEM students benefiting from these high-impact practises.

URE opportunities also tend to favour students who excel academically, a group that typically already knows about the benefits of UREs and protocols for obtaining research opportunities. Hence, increasing the number and accessibility of the opportunities available is ultimately important for increasing the diversity of those who graduate and work in the STEM field.

Establishing Opportunity

The Course-based Undergraduate Research Experience, or CURE, has been used as a means of altering this pattern. A CURE combines the use of science practices and collaboration with the aim of a novel discovery with broad relevance or importance. Through integrating UREs into courses, CUREs extend research opportunities to every student. While not a new practice, CUREs have historically been limited to courses for advanced students. SIRIUS CUREs begin in the introductory level courses, removing this limitation and expanding their scope.

The Sustainable Interdisciplinary Research to Inspire Undergraduate Success (SIRIUS) Project, which launched in June 2015, is a major classroom component of the River City Science Project, an investigation into the human impacts on waterways in Northern California. This project provides every undergraduate biology student at CSUS with real research experience related to the American River, which runs through the campus and has been listed as impaired since the 1970s.

‘We are, in essence, adopting the American River as kind of a living science laboratory. A laboratory big enough for collaboration between all of our students, faculty and staff.’

The PIs of SIRIUS worked for three years developing the ideas behind the project and securing its funding. ‘We are, in essence, adopting the American River as kind of a living science laboratory,’ Dr Landerholm says. Dr McDonald adds, ‘a laboratory big enough for collaboration between all of our students, faculty and staff.’

They note the advantage of being stationed in Sacramento, the capital of California, as it offers proximity to government agencies who are also concerned about the river systems, including the US Geological Survey, Environmental Protection Agency and US Fish and Wildlife Service. The long-term goal of SIRIUS is to develop a STEM education community that is focused on this scientific problem, built among students and faculty of varying disciplines.

Tools for the Next Generation

The two main aims of SIRIUS are to create a professional development program for participating faculty, using a Faculty Learning Community model, and to use the CUREs to study human impacts on the river, making the courses tangible and consequential. It has involved students getting the opportunity to solve real world problems and effectively teaching them to become scientists.

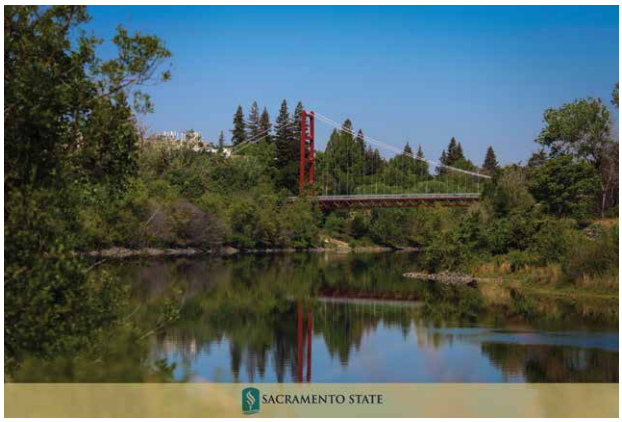
Dr McDonald comments that, ‘we think one of the most exciting (and important) aspects of this project is the collaborative way that our faculty, staff, administrators and students have approached curriculum reform.’ A significant proportion of the Department of Biological Science’s laboratory curriculum has been redesigned by SIRIUS in order to improve the experience for students, and the departments of Environmental Studies, Geology and Chemistry have each implemented course changes around the SIRIUS theme.

The PIs attribute the success of the faculty’s development to the group’s efforts to unify itself through a shared vision and common goal early on, as well as building a community that would continually engage in the projects’ primary practical activities. These included collecting and sharing data that demonstrated a need for curricular reform and encouraging each faculty member to develop research questions according to their interests and expertise. These activities started before the Faculty Learning Community was established and once a need was identified the team talked to faculty about what they wanted to do or achieve in the courses.

During the project, continuity is being maintained through summer workshops and academic-year meetings. The PIs, based on their experience and previously reported

evidence believe that Faculty Learning Communities who train and support faculty members are particularly effective for science departments as they adopt evidence-based teaching.

Regularly scheduled curriculum planning meetings occur during the year, and these have served as the venues for course-based group meetings. These are focused on assessing and evaluating the specific curriculum. At least one meeting of the whole group occurs each semester – using time blocks reserved for faculty and committee meetings – keeping the program cohesive. These meetings are open to the entire department and this has helped to recruit additional members of the faculty.



Each summer, faculty gather for a multi-day workshop to peer-review the curriculum and collaboratively revise scientific work plans, student learning outcomes and classroom assessments. The PIs of the SIRIUS project and their colleagues considered it important to allow for flexibility in the design and scheduling of the projects, as some CUREs have required longer development times, while others have required re-evaluation of their research questions and protocols even after they started work.

The Real Impacts of Real Research

The two PIs of the SIRIUS project have observed first-hand the positive impacts of providing research opportunities to undergraduate biology students at the introductory level. Surveys and focus groups determined that significant gains in laboratory self-efficacy occurred in students who reported the lowest levels of confidence at the beginning of the semester. This is in agreement with other studies that have shown participating in research early in training can increase confidence and create higher levels of retention.

They also highlight the importance of engaging women and underrepresented demographic groups in scientific research. Following their observations in SIRIUS, women and students eligible for financial assistance grants enjoyed increased confidence in their laboratory skills.

Research conducted on CUREs suggests that their benefits in preparing those participating in STEM may be comparable to that of an extracurricular URE or an internship. Improvements in confidence, scientific identity and attitudes towards science are among the results that the PIs have observed. In one semester, the number of students who wanted to pursue a career in science was 5% at the beginning of the first course and 20% at the end of the second course in the series. Helpfully, the team have also identified some misconceptions that students hold regarding the nature of research that is providing insight for how faculty might introduce the practice of research to students.

The SIRIUS team also believe that extra-curricular research experiences can lead to higher acceptance rates to postgraduate programs. UREs can lead to more perseverance in STEM subjects giving students the encouragement they need to remain inspired and confident. The higher level of complexity practiced also generates more thorough content comprehension of undergraduate studies and better critical thinking skills. The two PIs explain that SIRIUS teaches effective use of a variety of technologies, and further expect the project to foster a deeper understand of the scientific process, critical thinking and engagement.

Positive impacts have also been observed with faculty who have developed their own CUREs. Data suggest that the projects leave faculty members feeling more engaged, excited about teaching and often provide a point of focus for their academic careers. Not only did they enjoy the teaching experience and appreciate the integration of their own research interests into the courses, some of them received more attention from the academic community, which has led to promotion and increased publication and funding.

Further, the PIs have made observations about the dynamics of collaborating with others in such a project. They note that involving multiple STEM disciplines means more interdisciplinary engagement, but also requires conversations around the similarities and differences inherent to the disciplines.

While most of the research to date has focused on the impacts of the SIRIUS CUREs on introductory level students, similar analyses of upper-division students in CUREs as well as those participating in traditional UREs is underway. Additional assessments, such as those that measure critical thinking and course-specific aptitudes are also being employed to examine students' abilities to engage with higher levels of study.

Contributions at All Levels

The PIs recently submitted a grant to the National Science Foundation Improving Undergraduate STEM Education (IUSE) Program – Institutional and Community Transformation – for SIRIUS II. The SIRIUS II project will retain the focus on the American River but will extend the project to other waterways in Northern California and their surrounding ecosystems. It will expand on the work of the first SIRIUS project and will involve 10 STEM disciplines across CSUS, including engineering, computer science, physics, mathematics and statistics, and will work with four nearby community colleges. SIRIUS II will go further to integrate research requiring collaboration across disciplines, exposing students to truly cross-disciplinary projects.

The SIRIUS project can be essentially replicated by any university's science departments. The work of Drs McDonald and Landerholm and their SIRIUS colleagues has shown that undergraduate students can significantly benefit from being given real scientific problems to engage with. Rather than being alienated by a higher level of challenge, once trusted with the tasks, the overall long-term impact on students can make them stronger as learners and contributors to STEM as a whole.

Meet the researchers

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USA

Dr Kelly McDonald is an associate professor and the assistant chair of the Department of Biological Sciences at California State University, Sacramento. She obtained her PhD from the University of Florida in Biochemistry and Molecular Biology. Her academic career began at American River College in Sacramento, California, where she taught biotechnology and microbiology and served as an Education Outreach Coordinator, Assistant Director and Interim Director of the North Valley Biotechnology Center. Dr McDonald joined the faculty at Sacramento State as a science education specialist in 2009. She teaches courses related to molecular and cellular biology, coordinates the Graduate Teaching Associate Program and the Pre-teaching Internship Program for the Department of Biological Sciences. She is a leader in faculty professional development and her research focuses on broadening participation and improving learning experiences for students in the Science, Technology, Engineering and Mathematics disciplines.

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Dr Thomas Landerholm is a professor of Biological Sciences and a Principle Investigator of the SIRIUS Project with Dr Kelly McDonald. He obtained his PhD from Baylor College of Medicine in Biomedical Sciences in 1999. His academic career began at Sacramento State in 2002, and he has been a leader in the Department's curriculum development, serving as chair of the Task Force charged with revising the undergraduate curriculum, serving as co-chair of the Cell and Molecular Biology Curriculum Subcommittee and serving as principal course designer for multiple undergraduate and graduate courses in cell, molecular and developmental biology. Dr Landerholm also conceived and developed the campus STEM Initiative, to promote student recruitment, retention and success in science, and to develop regional STEM education and workforce programs. Dr Landerholm also founded the Center for STEM Excellence and served as its Director for the first five years. He also conceived and initiated the River City Science Project, whose goals are to establish a science identity around the American River, and research and curriculum collaboration among the many scientific disciplines in the Sacramento Community.

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SACRAMENTO STATE

BIG STUDENT EXPERIENCES IN NANOTECHNOLOGY

Nanotechnology is poised to be one of the most critical technologies of the near future, yet exposure to nanotechnology techniques is limited for many college students. **Dr Andrea Holmes** and **Dr Christina Wilson** of Doane University in Crete, Nebraska, are partnering with the Karlsruhe Institute of Technology in Karlsruhe, Germany, to provide students with unparalleled experiences in nanotechnology research for biomedical applications.

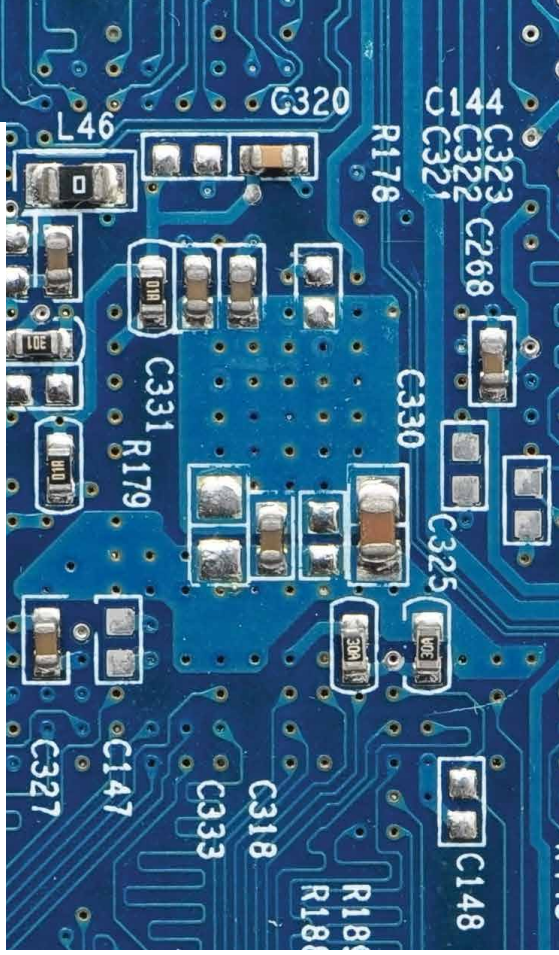
Growing up in Germany, Dr Andrea Holmes of Doane University never imagined finding herself living in the corn fields of Nebraska, but after completing her PhD at New York University and a post-doctoral position at Columbia University, she found herself looking for new opportunities and a change of pace in her environment. She applied to teach at Doane University, a small private university in southern Nebraska surrounded by corn fields.

Years later, Dr Holmes has found a wonderful home and community at Doane and is using her skills in nanotechnology research and international roots to provide incredible research and educational opportunities to her students. Through a partnership with the Karlsruhe Institute of Technology (KIT) in Karlsruhe, Germany, she has secured National Science Foundation funding for a program that provides International Research Experience for Students, that covers travel and expenses for undergraduates to perform collaborative research abroad.

Through this program, Dr Holmes has helped many Doane students expand their horizons while working on projects related to her specialties in nanotechnology, biosensing, and biofilm research. Her students will spend three summers conducting research at KIT in Germany, and after their first year are already well on their way to successful research careers of their own.

The Future of Detection

A major challenge in many fields is the accurate detection and identification of substances outside the laboratory. From identifying water contamination in streams, to locating explosives in war zones, to testing for performance enhancing drugs, there are many industries that could benefit from the ability to perform substance detection, on site, in real time. The major thrust of Dr Holmes' work, and her students' international research, is a nanoprinted sensor called the DETECHIP®, short for detection chip.



'We have developed new colorimetric sensor tests that are small and portable to detect drugs of abuse, pesticides, steroids, explosives, and warfare agents like nerve gases.'

Utilising state of the art nanoprinting of micropatterns, Dr Holmes and her team have developed a novel chip that can be adapted to multiple substances, printed on many types of surfaces, that provides real time results in the form of colour changes that can be distinguished and parsed by a computer to identify the substance identity. Dr Holmes describes how they have, 'developed new colorimetric sensor tests that are small and portable to detect drugs of abuse, pesticides, steroids, explosives, warfare agents like nerve gases, and biological molecules that play a significant role in bacterial infections.'

During their stay at KIT in Germany, Dr Holmes' Doane students worked with nanotechnology experts' Dr Michael Hirtz and Dr Pavel Levkin on projects aimed at both making the chips smaller and increasing the range of materials that they can be printed on. In addition,

‘Our research involves surface modifications to create anti-fouling materials that could be used on medical implants to prevent biofilm infections during surgery or to prevent biofouling on marine ships.’

students are helping Dr Holmes and the KIT researchers to identify imaging technologies that could be used to read the DETECHIP® in field situations – so that this incredible technology can find its way out of the lab and into the hands of doctors, soldiers, scientists, and specialists working in countless different conditions and situations.

The Doane students recently completed their first summer of the program at KIT and the feedback has been overwhelmingly positive. These students from a remote area of the American Midwest are gaining broader cultural exposure while learning valuable skills in science and technology that they can carry forward in their careers.

Many have already expanded the scope of their intended research projects, as well as produced publications and presented at national science conferences. Their work is already helping Dr Holmes and the researchers at KIT to improve and expand DETECHIP® capabilities and is anticipated to yield even more impressive results as the program continues.

New Frontiers in Biofilm Research

Dr Holmes’ incredible DETECHIP® sensors may also be used to detect the faint signatures of a biofilm-related infection. The gradual accumulation of multiple species of bacteria and other microbes on a surface, creating a layer known as a biofilm, can create significant challenges in multiple aspects of society. Biofilms are communities of diverse microbes that occur on a variety of surfaces, from the algal slime on the hulls of boats, to infections on medical implants, to the plaque on your teeth.

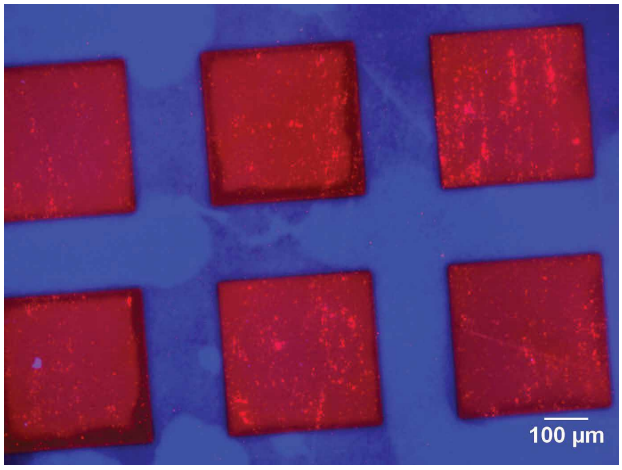
While the types of microbes in these biofilm communities may vary greatly, what they share in common is a diverse blend of organisms each with unique strengths and weaknesses contributing to the community, often making them antibiotic resistant, adaptable, and impervious to many standard prevention techniques. These masses of single-celled organisms often take on unique traits and abilities that none of the individual species possess on their own, such as the ability to convert toxic chemicals to safe compounds in waste treatment plants or to corrode metal in industrial settings.

Biofilms thrive in wet environments, so surfaces that are constantly under water, such as marine equipment, frequently accumulate biofilm masses that can interfere with functionality. Coatings of biofilm block fishing nets, slow down boats, and serve as reservoirs for aquatic disease, costing fishing, aquaculture, and shipping industries millions of dollars every year. Biofilms are also a major problem in many hospitals, where they can accumulate on equipment and medical devices, presenting major health challenges when a patient acquires an antibiotic resistant biofilm-related infection.
Biofilms are among Dr Holmes’ and her team’s chief research interests – she specialises in using nanotechnology to create anti-fouling surfaces and materials that are resistant to the accumulation of biofilms by design. ‘Biofilm infections are one of the worst antibiotic resistant hospital acquired infections,’ she describes. ‘Our research involves surface modifications to create anti-fouling materials that could be used on medical implants to prevent biofilm infections during surgery or to prevent biofouling on marine ships.’

Biofilms start when a few microbes find a way to attach to a surface in a moist location, and more single-celled organisms of different species gradually join. Surfaces that prevent bacteria from binding to them are able to stay biofilm free, even in conditions that normally allow biofilms to flourish. The ability to control the attachment of biofilms to surfaces can be used to prevent unwanted biofilm-related infections and to harness the positive characteristics of biofilms, such as using them to clean up contaminated soil and water or bioremediation.

By finding ways to make these surfaces easier and less expensive to produce, Dr Holmes and her team including research scientist Dr Christina Wilson, are working to help make the world a cleaner, safer place.

‘We want to study how biofilm can be used in bioremediation, such as in cleaning wastewater that contains pesticides that are prevalent in Nebraska and the Midwest, such as Atrazine which is suspected to cause cancer.’



In the summer of 2017, Dr Holmes’ undergraduate researchers left Doane University to spend eight weeks in Germany at KIT working on technologies to help scientists better study biofilms under the mentorship of Dr Wilson. The students used micro and nanolithography techniques to create micropatterned surfaces on a microscope slide – wells of the pattern attract water and facilitate biofilm growth, while the dividing lines between wells repel water and are inhospitable to bacteria.

These microarrays allow for the growth of hundreds of unique biofilms on a single slide, making it easier for researchers to study these fascinating bacterial communities. This technology can be used to help scientists advance our understanding of how biofilm communities function and how they develop their unique properties, such as antibiotic resistance.

Dr Holmes’ team hopes that this technology will lead to advancements in treatments for biofilms that could help transform healthcare, and potentially the ability to harness the unique properties of biofilms for applications that benefit humankind. By learning to control the activities of biofilms, it could be possible to utilise them to serve human needs rather than them serving as a nuisance.

Micropatterns for Major Results

Micropatterned surfaces are used in many biological and medical applications, such as screening for proteins or antibodies that might indicate the presence of a disease. Nanoscale patterns are designed to specifically adhere to a unique part of a biological compound, however these binding sites are often susceptible to getting clogged up by random fragments of proteins, reducing their efficiency and accuracy, sometimes leading to ambiguous results.

Typically, a mechanism has to be employed to keep the wrong materials from adhering to the micropattern, so that observers can be confident that the desired compounds are bound if they are present. In research applications, the most common way to prevent non-specific protein binding is by using bovine serum albumin (BSA).

BSA is a special protein from cow blood serum which can be suspended into a sticky fluid that effectively blocks any surface sites that are amenable to non-specific binding, thereby encouraging the desired protein to bind at the intended sites and not at the non-specific sites. Recently, through collaborating with scientists at KIT, Dr Holmes and her students developed a method of printing micropatterns that are highly attractive to the desired protein on coated surfaces that can repel erroneous proteins, minimising non-specific binding without the use of BSA.

In the future, these micropatterns can be used to pull out a desired protein accurately and efficiently even from biological fluids containing many complex and varied proteins. This technology has the potential to revolutionise biomedical research and testing by increasing both the ease of use and accuracy of many common screens.

A Healthier Future

Dr Holmes’ and her team’s goals for the future of her nanotechnology research are ambitious and could transform many aspects of modern life. She explains, ‘for the sensor project, a smart phone application needs to be developed so that the sensors can be taken in the field by anybody without much training, and one can take an image with a smart phone, upload it, and the app will provide the identity of the unknown substance.’

With this technology, it would be possible for researchers, military personnel, and environmental workers, to more easily obtain accurate substance identification miles from a laboratory, enabling real time informed decision making for people in the field. Dr Holmes, Dr Wilson and their team of students also hope to build upon their successes in accelerating biofilm research, to learn how to harness the unique abilities of biofilm for the greater good.

Dr Holmes says, ‘we want to study how biofilm can be used in bioremediation, such as in cleaning wastewater that contains pesticides that are prevalent in Nebraska and the Midwest, such as Atrazine which is suspected to cause cancer.’ She hopes that by learning more about how biofilms form and develop their unique properties, she will be able to put them to use cleaning up the world’s water supply and restoring clean, safe drinking water to agricultural communities, where water sources are often contaminated with pesticides and other chemicals that are suspected to have dangerous long-term health effects.

Through the marriage of nanotechnology and biology, Dr Andrea Holmes and her team are engaged in research that protects human health by detecting toxic chemicals, providing safer hospitals, and developing technologies to improve the environment. They are working to ensure that this research will carry into the future by providing transformative educational and training experiences for the next generation of world class scientists at Doane University.

Meet the researchers

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Andrea Holmes studied biology at the University of North Florida and went on to study Organic Chemistry, earning a PhD from New York University in 2004. She continued on to post-doctoral positions at Columbia University, before joining the faculty at Doane University in Crete, Nebraska in 2005. Dr Holmes currently serves as a Professor of Chemistry at Doane, where she has mentored numerous undergraduate and graduate students in applying nanotechnology techniques to biomedical and chemical challenges. She received the prestigious Early Career Award from the National Science Foundation from 2008–2014, funding from the National Science Foundation, Department of Defense, and in 2015 received the Henry Dreyfus Teacher-Scholar Award, all in honour of her exemplary teaching work at Doane University.

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Christina Wilson studied Chemical Engineering at Kansas State University and went on to obtain her PhD in Chemical and Biomolecular Engineering at the University of Nebraska-Lincoln in 2016. She has supported the International Research Experience for Undergraduate Students (IRES) program as an undergraduate mentor at the Karlsruhe Institute of Technology. She is currently pursuing post-doctoral research with the Centre for Undergraduate Research of Biofilms under the mentorship of Dr Andrea Holmes at Doane University.

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REFERENCES

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COLLABORATING FOR A CLEANER FUTURE

The greatest challenges facing humanity over the next decades involve finding renewable sources of energy and finding ways to restore natural resources such as clean water that have been polluted by industrialisation. **Dr Justyna Widera-Kalinowska** of Adelphi University uses innovative nanohybrid materials to address these problems and is engaged in an international effort to train the next generation of chemists to build a cleaner future.

As an ever-growing human population puts its strain on the resources of our planet, it is becoming more and more essential for humanity to turn to innovative solutions that can provide us with clean sources of energy and allow us to engage in environmental remediation to repair the damage pollution has done to our natural resources.

Developing sustainable power sources to replace the burning of fossil fuels will be essential to stopping global climate change, and without intervention, many areas of the world will soon face shortages in clean, drinkable water. It is critical that today's college students in science, technology, engineering, and mathematics (STEM) be prepared to contribute to solutions for these global level problems and that the students entering these fields be as diverse as the populations they serve. It will take international cooperation and collaboration between scientists and policymakers to ensure that our planet is a safe and healthy place for future generations.

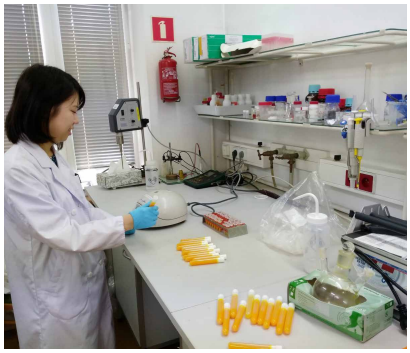
The United States National Science Foundation International Research Experience for Students (NSF–IRES) program offers funding for educational programs that provide innovative research opportunities to undergraduate students. Dr Justyna Widera-Kalinowska, an associate chemistry professor at Adelphi University in Garden City, New York, saw an opportunity to facilitate international scientific collaboration in energy and environmental materials research, while also providing career building opportunities for minority and female students of STEM.

Through a partnership with Warsaw University in her native Poland funded by the NSF–IRES, Dr Widera-Kalinowska provides diverse and underprivileged students the opportunity to receive world class training and early career experience in nanomaterial research for environmental remediation with renowned European researchers in Poland over their summer, along with additional support and professional development in the US during the school year.

Toxic Problems

As the world's population grows exponentially each year and industrialisation spreads further around the globe, the depletion of non-renewable fossil fuels keeps humanity constantly on the edge of a worldwide energy crisis. Further, the burning of fossil fuels pollutes our land, air, and water, and has brought on global climate change that threatens human health, commerce, and societies, along with destroying biodiversity in ecosystems around the world.

The limited availability of fossil fuels, coupled with their dangerous side effects of pollution and global climate change, demands the development of clean and sustainable alternate energy sources. Solar energy presents one of the foremost options to meet the demand for clean energy, however advances in the efficiency and power of solar panels, along with the development of low cost manufacturing and installation methods, are necessary before solar energy becomes a viable solution.



‘I would like to continue my efforts to study new materials for solar cells and photocatalysis applications and I will keep engaging students in this fascinating journey of science discovery.’

Developments in photovoltaic nanohybrid materials may offer the advances necessary to make this happen. Nanohybrid materials are made from a combination of different types of substrates, blended together such that some of the structural integrity of each material is maintained at the molecular level and the resulting hybrid performs with characteristics of each of the original materials, sometimes also taking on new properties. A photovoltaic nanohybrid consisting of various nanomaterials produces an electrical current when exposed to light, making them an ideal material for solar panels.

Among the other greatest challenges poised to face humanity in the near future is the decreasing availability of clean drinking water. In many developing nations this is already a major issue, with access to clean water often most limited in the most vulnerable populations. While the planet is covered in water, about 97% of it is undrinkable salt water, and another 2% is contained in glaciers and other inaccessible forms.

Only about 1% of the earth’s water is drinkable, found mostly as groundwater. As industrial activities, agriculture, and domestic water usage continue to generate large amounts of dirty wastewater in both developed and developing countries worldwide, reservoirs of clean water shrink by the day. Without intervention, it is anticipated that over the next few decades water scarcity will become a global problem, even in regions of the world that are currently considered water rich.

Once again, nanomaterials could offer a ray of hope. Photocatalytic nanomaterials offer a novel way to clean industrial pollutants and waste from water sources. These materials accelerate specific chemical reactions when exposed to a polluted water sample and light, generating the energy necessary to break down organic wastes into harmless carbon dioxide and clean water. These materials could be used in water treatment facilities to not just attempt to filter out, but truly cleanse dangerous pollutants from wastewater and make it safe and drinkable again.

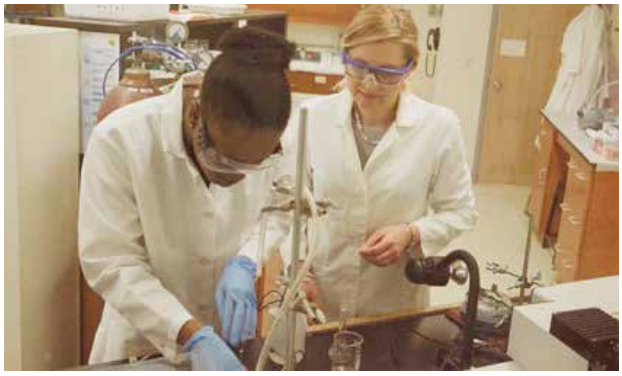
Brilliant Minds

Nanohybrid materials offer a great deal of promise for environment saving technologies, and as an expert in these novel tools, Dr Widera-Kalinowska wanted to get more students involved in this fascinating area of research early in their careers and wanted to find a way to connect them with experience of study abroad in her homeland of Poland.

She recognised the demand for more researchers with an understanding of these innovative materials and a need to increase diversity and inclusion in the world of nanomaterial science and STEM in general. Working with Professor of Chemistry Magdalena Skompska from Warsaw University, she applied for an NSF–IRES to form a partnership between the universities and support the training of undergraduate STEM students, particularly from minority and underprivileged backgrounds and in 2016 secured funding for the training of twelve undergraduates, four students a summer over three years.

The program has a focus on recruiting students that are typically underrepresented in STEM fields, such as women, students of colour and individuals from disadvantaged economic backgrounds. The goal of the program is to get students involved in nanomaterials research for environmental applications early in their careers, with the hope that they will continue fostering international collaboration in developing novel solutions for the challenges that face humanity in the coming decades.

Further, the program strengthens STEM education at both Adelphi and Warsaw University and provides a foundation for strong future collaborations between material chemists from the two institutions.



The program kicked off in the Fall semester of 2016 at Adelphi University, with an independent study chemistry course that any interested student could join. The course offered weekly one-hour classes, where students could gain exposure to foundational concepts, techniques, and applications of material science and research. From this class, Dr Widera-Kalinowska chose the four most promising students to participate in a second course in the Spring of 2017.

Throughout the second semester, the four NSF–IRES funded students received regular one on one mentorship from Dr Widera-Kalinowska, training in basic electrochemistry and nanotechnology techniques, and cultural preparation for their trip to Poland. An additional student was able to secure funds to participate in the program through a McDonell Summer Fellowship, thus five students who were female and/or minority students, were able to travel to Warsaw for eight weeks in the summer of 2017.

Students were able to focus on their area of interest, splitting evenly between photovoltaic and photocatalytic research. While in Warsaw, the students received immersive training in nanohybrid material creation, participated in research in both photovoltaic and photocatalytic materials, and enjoyed cultural activities and excursions around Poland.

Clean Solutions

The initial summer of Widera-Kalinowska's NSF–IRES program was a great success, producing findings in both photovoltaics and photocatalysis that could inform future technologies in these fields. The students researching photovoltaics for solar energy applications focused on the nanoscale interactions between two promising compounds, polyaniline and cadmium sulphide nanoparticles that produced electrical current when exposed to solar light.

They found that the ratio of the components to one another impacted the material's efficiency in converting solar energy for the devices they built, due to the variations in their bandgaps, or the distance electrons had to travel between conducting surfaces in different configurations of the material. This finding allowed them to predict which compositions of the nanomaterial would be the most effective at harvesting light energy, a critical factor in making solar energy a viable solution for sustainable energy challenges. The students will continue in this vein of research, working to develop more efficient photovoltaic devices that one day could play a role in providing alternative energy sources to the world.

The students researching photocatalytic materials for water clean-ups and environmental remediation also made substantial findings. They built novel composites out of varying concentrations of nitrogen doped titanium dioxide, cadmium sulphide, and a conducting polymer (poly-1,8-diaminocarbazole) to obtain nanohybrid materials with varying bandgaps that could effectively degrade organic pollutants while being stable enough for practical applications.

Nitrogen doped titanium dioxide and cadmium sulphide are known to be an effective combination of semiconductors for photocatalysis, however, the cadmium sulphide quickly degrades in a standard composite. The students' addition of a stabilising polymer (poly-1,8-diaminocarbazole) aimed to make the material more enduring. For the photocatalyst testing experiments, they used 4-chlorophenol, a common industrial chemical that is regularly found as an environmental contaminant and has a similar structure to many other common toxicants.

This chemical can be harmful to humans if swallowed, and is highly toxic to aquatic life, thus is a prime candidate for removal from freshwater systems in environmental remediation, as well as removal from city water supplies. The novel nanohybrid materials the students produced were used to successfully degrade 4-chlorophenol in the presence of light and the addition of the polymer made the material much more stable than previous composites. The students' research team hopes to continue developing this composite material into something that could someday be a practical choice for large scale water purification efforts.

A Bright Future for Collaboration

Now entering its second year, the US-Polish nanohybrid materials program is poised for another successful year and has already begun recruiting the next round of NSF–IRES students. Dr Widera-Kalinowska describes how, 'the students that participated in the first year will continue working in the laboratory to extend the research they began in the summer and will provide mentorship and support to the next cohort of students.'

These students will form the next generation of material scientists, poised to find solutions to our greatest challenges and provide a cleaner, more sustainable world for years to come. She hopes that, 'all of this helps them to become better professionals and more educated citizens of the world. I would like to continue my efforts to study new materials for solar cells and photocatalysis applications and I will keep engaging students in this fascinating journey of science discovery.'

Meet the researcher

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Justyna Widera-Kalinowska began her education in Poland, obtaining her MSc in Chemistry from the University of Lodz in 1995 and her PhD in Chemistry from the University of Warsaw in 2000. She went on to serve in multiple prestigious post-doctoral and commercial research positions in Germany and the United States, before joining the faculty at Adelphi University in the Department of Chemistry in 2005. She currently serves as an Associate Professor of Chemistry along with holding a position as the Director-at-Large for the New York section of the American Chemical Society. Her research focuses on nanotechnology and conducting polymers for sustainable energy and environmental remediation applications. Dr Widera-Kalinowska is deeply committed to promoting inclusion and diversity in chemistry and STEM as a whole.

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Faculty of Chemistry, Warsaw University, Poland

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ADELPHI UNIVERSITY
NEW YORK

S-COAM: SUPPORTING STUDENTS IN STEM EDUCATION

A report by the US National Science Foundation found that the State of Pennsylvania ranks below the national average on the proportion of mathematics, science, and engineering degrees conferred to students. The Scholarships-Creating Opportunities for Applying Mathematics Program, developed by **Drs Yu-Ju Kuo** and **Frederick Adkins** at Indiana University of Pennsylvania, provides financial aid and a variety of academic opportunities to students in need.

Over the past few decades, rapid technological advancements have prompted growth and transformation within many scientific fields, highlighting the rising need to adequately train future generations in the fields of science, technology, engineering and mathematics (STEM).

The Science and Engineering Indicators 2008 report by the US National Science Foundation (NSF) found that the State of Pennsylvania ranks below the national average on the portion of conferred STEM degrees, with an average of 29.5%, compared to the national 29.9%. The state ranks even lower in the percentage of advanced degrees out of all degrees attained in STEM areas, with an average of 21.3%, compared to the national 24.2%.

A 2007 report highlighted the even greater contrast of these numbers with the portion of STEM degrees conferred in other nations, with percentages such as 38% in South Korea, 47% in France, 50% in China, and 67% in Singapore.

There could be several reasons why a low proportion of American students are attaining scientific degrees compared to other countries, including the need for additional recruitment, improved retention, and mentoring of students who do not feel confident about their skills in mathematics. In fact, the number of students pursuing science and technology degrees who decide to take advanced mathematics courses appears to have declined, with many students questioning their mathematical abilities.

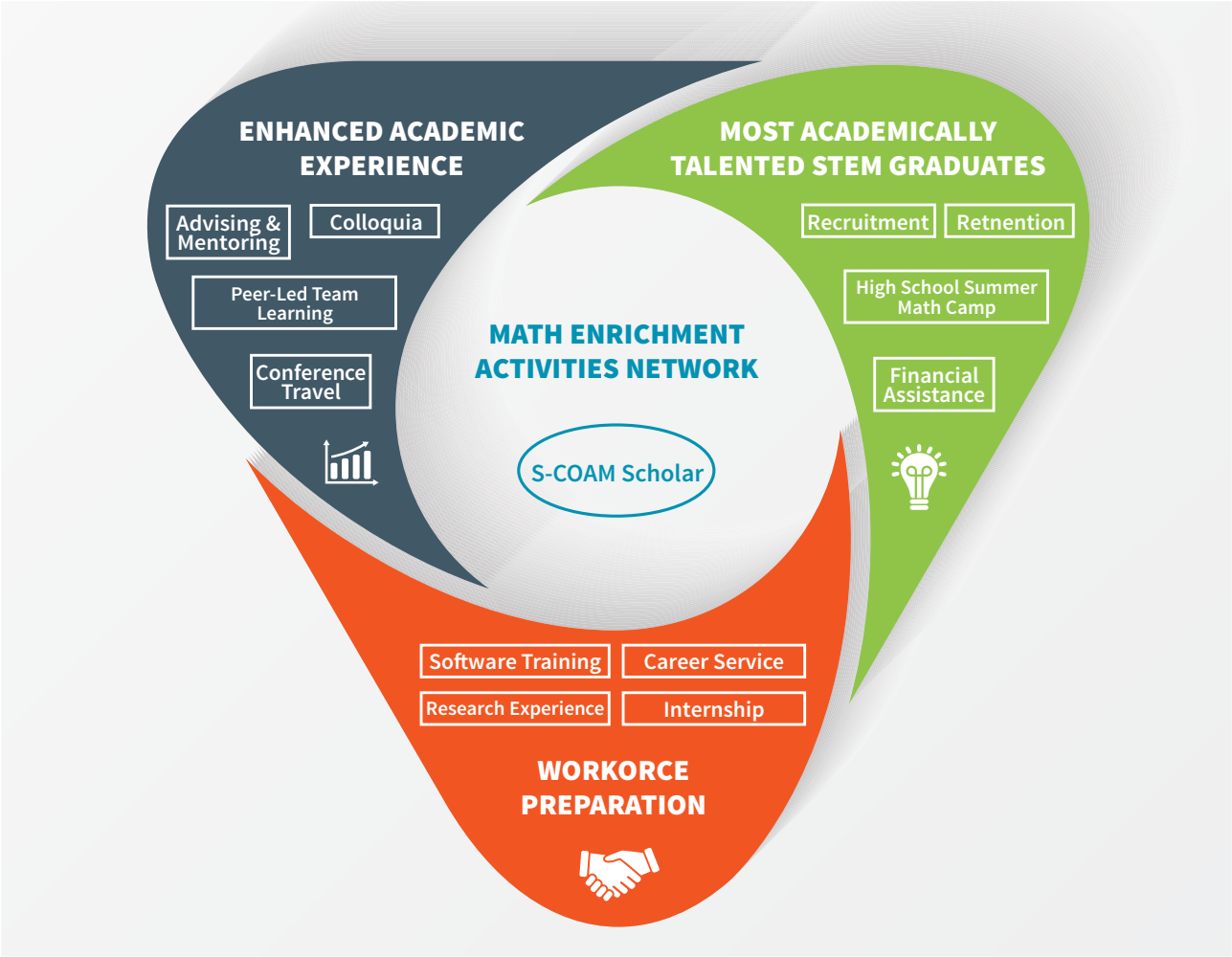
The state of Pennsylvania also has a higher average in-state cost of higher education attendance of $19,017, which represents 50.1% of disposable income. At the Indiana University of Pennsylvania (IUP), 63% of STEM students show a degree of financial need, with an average un-met need of $5,600, even after applying for scholarships and student loans.

Moreover, many state-specific aid programs have shifted from assistance based on financial need to merit-based aid, which tends to favour wealthier students over lower-income ones.

All these factors highlight an impelling need for programs that offer both financial and academic support to disadvantaged students, who are looking to pursue further education and careers in STEM-related fields.

The S-COAM Program

On a quest to meet the needs of low-income students with a passion for STEM disciplines, Drs Yu-Ju Kuo and Frederick Adkins, from Indiana University of Pennsylvania, have developed the Scholarships–Creating Opportunities for Applying Mathematics (S-COAM) Program. The S-COAM project was first introduced in 2010, funded by the NSF's Scholarships in Science, Technology, Engineering and Mathematics Program. It received further funding in 2013, which allowed it to continue until 2017.



Between 2010 and 2017, S-COAM assigned scholarships to a total of 120 students with financial aid, while also connecting them with other peers and field experts, empowering them to pursue advanced mathematics courses, and offering other academic opportunities.

S-COAM has several objectives, including improving retention for students pursuing degrees in mathematics, enhancing diversity among STEM students, and increasing recruitment for IUP's Applied Mathematics Master's degree.

Mathematical skills have been identified as a common qualification or ability required to succeed in the top 15 jobs. Despite this, IUP is effectively the only university in the Pennsylvania State System of Higher Education to offer Master's course in Applied Mathematics, making it a vital institution for the preparation of applied mathematicians. 'With the scholarships and assistantships from our Master's program, we will be able to recruit more qualified students who cannot otherwise afford to attend and further prepare them for employment in mathematical science areas,' Drs Kuo and Adkins explain in their proposal. 'By providing scholarship and mentoring programs to our undergraduate students, more students will remain in the mathematics field resulting in greater likelihood of student entering the related workforce.'

As part of its greater goals, the project also aims to create a pipeline for recruiting STEM undergraduates and strengthening students' leadership abilities, technical skills, and their aptitude for life-long learning.

The program directors are personally committed to mentoring and advising each of the participating students, who can take part in different academic initiatives to strengthen their skills and connections in the field. Spanning over the course of three academic years, the program offers students research and internship opportunities, conference travel support, and the chance to take part in hands-on technology workshops.

Meanwhile, participants can connect with other peers specialising in STEM subjects, as well as with a network of academics and experts operating in areas that could be of interest to them. This increases their awareness of STEM-related careers, encouraging them to establish connections that could prove valuable in the future.

A Valuable Support Network

The opportunities and activities included in the S-COAM program are quite varied in nature, addressing the project's different objectives.

At monthly cohort meetings, students network with those returning from internships, and ask them questions about job searching, interviews, and their overall experience with working in STEM-related fields. Taking inspiration from their more experienced peers, the students are also encouraged to pursue summer research programs and internships. For instance, the program has established an ongoing relationship with NASA, with three successful internship placements, one of which turned into a long-term hire.

During monthly meetings, teams of students are asked to present results of mathematical modelling questions, sharing their knowledge of applied mathematics. 'Each monthly meeting also features a student designed professional development activity with recent contributions spanning understanding your personality and communication preferences, hands-on technology training, and new developments in scientific research,' explains Dr Kuo.

In addition to the monthly meetings, all students participating in the S-COAM program are asked to attend at least four colloquia, seminars, or workshops. These activities are open and enhance the academic and research environment of the larger university community, providing everyone access to cutting edge technology training. The program provides students with mathematics knowledge that is applicable to scientific disciplines, strengthening their preparation for advanced degrees in the areas of science, technology, engineering, and mathematics.

Program Evaluations

An external evaluation of the S-COAM program carried out by Dr Debra Moore, co-director of the Department of Instruction and Learning at the University of Pittsburgh, assessed the project's outcomes and its potential benefits for participating students. The materials used to investigate the outcomes of the project included a series of phone interviews with participating students, end of semester surveys, former annual reports, and other documentation from students who graduated from the program.

According to the survey and interview data, most students felt that participating in S-COAM-related activities helped them to feel more connected with their peers and with faculty of the mathematics department. They also felt that the program exposed them to new career opportunities and helped them to develop critical skills that could be applicable in future work-settings. One student who participated in the program said: 'It made me more excited to join the workforce because it showed us applications of what we were learning.'

Many participants appeared to be particularly pleased with the programming and presentation skills they acquired. Statistics revealed that S-COAM also successfully increased the number of math major, minor, and graduate students at IUP, encouraging a stronger research culture among students and the mathematics department. 'Overall, students speak highly of participating in the program and have been immensely successful in securing full time STEM employment or admission to graduate school STEM programs they find satisfying and enjoyable,' reads the program's 2017 evaluation report.

Students who participated in the program pursued further science-related studies and careers, with high-success rates in securing full-time employment and being accepted into graduate school programs. Many of the students appreciated the interdisciplinary nature of S-COAM, which focused on the possible applications of mathematics within a great variety of scientific fields. 'In SCOAM, we were exposed to different fields and the workforce is interdisciplinary. It is not just math people working with math people,' said one student who was interviewed.

Another important goal that the project has met is that of improving opportunities for students in need of financial support. Several interviewees praised the effects of the funding they received, as well as having travel expenses covered when attending colloquia and conferences. One student who completed the program said: 'After a 4-year degree and accumulated debt, I wouldn't have gone to graduate school if not for the money and I would not be where I am if not for the funding.'

The Future of the S-COAM Project

Constant progress within science and technology sectors is placing greater pressure on education, prompting institutions to find new ways of introducing students to STEM-related subjects, so that they can meet the needs of current and future workplaces.

Past NSF reports have highlighted the low percentages of students pursuing degrees in STEM-subjects compared to several other countries – a trend that seems to be further accentuated in the state of Pennsylvania. The S-COAM project has been addressing this issue, while trying to enhance collaboration between students and faculty members at IUP, increasing students' interest in mathematics, and improving possibilities for minorities, women, and financially disadvantaged students.

So far, the program appears to have successfully met its main goals, motivating students to be more engaged in the study of STEM-subjects, providing valuable skills and career opportunities for their futures, and promoting networking among peers and faculty members. Past students took full advantage of the workshops, colloquia, and seminars available to them, with many attending more activities than required.

Due to the positive outcomes of the S-COAM program, Dr Kuo and Dr Adkins have recently been awarded further funding to continue running it (https://www.nsf.gov/awardsearch/showAward?AWD_ID=1742304&HistoricalAwards=false). The new project includes peer-to-peer academic support for STEM freshmen and financial support for summer research.

Initiatives such as S-COAM could make a huge difference in the state of Pennsylvania, vastly improving possibilities for students in financial need who are passionate about STEM-subjects, while renewing the interest of younger generations for the highly relevant and fascinating field of applied mathematics.

Meet the researchers

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Dr Yu-Ju Kuo is an Associate Professor and the co-coordinator of the MS program in Applied Mathematics at the Indiana University of Pennsylvania. She achieved a BS in Applied Mathematics from the Tatung Institute of Technology and an MS from the National Chung-Hsiu University in Taiwan, as well as a PhD in Computational Mathematics from Arizona State University and an MS in Computational Finance & Risk Management from the University of Washington. Dr Kuo has published several papers addressing a variety of mathematical applications. She has also been working to create opportunities for students who wish to deepen their knowledge of scientific topics or pursue a career in mathematics.

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Dr Frederick A. Adkins is a Professor of Mathematics at the Indiana University of Pennsylvania and the co-director of the IUP Software Development Center in Indiana. Dr Adkins attained a BS in Mathematics, Computer Science & Secondary Education from Concordia College, as well as an MS in Mathematics, an MS in Mechanical Engineering, and a PhD in Applied Mathematical & Computational Sciences from the University of Iowa. He has published many papers exploring complex mathematical and computational problems. Dr Adkins has been actively advocating for improvements in science education, trying to open opportunities for students who might wish to pursue a career in science and mathematics.

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FUNDING

US National Science Foundation

INDIANA UNIVERSITY OF PENNSYLVANIA

DIVERSITY

PROMOTING DIVERSITY IN STEM EDUCATION

Inequality and lack of diversity remain thorns in the side of scientific progress. In 2015, the US National Science Foundation reported that about half of the science and engineering workforce in the USA is white and male, despite the fact that white males make up less than one third of the population. This statistic is just one of many emphasising the need for our scientific workforce to better represent the general population.

Embracing difference, whether that relates to gender, ethnicity, socioeconomic background – or any other demographic – is essential not only for reasons of equality but for the promotion of excellence in science. A truly diverse workforce should represent the widest possible range of backgrounds, perspectives, and experiences.

Why is diversity so important to scientific excellence? Because greater diversity in a workforce creates greater potential for thinking outside of the box and for driving forward new and different ways of thinking. Pushing forward the boundaries of existing knowledge, challenging the status quo, and creating new ways to approach old problems are, after all, fundamental to scientific innovation.

While progress has certainly been made, there is much still to be done towards creating a more representative and diverse workforce in science. When we delve more deeply into the statistics, a complex pattern emerges. According to the Royal Society, females are not underrepresented in science when UK data are considered overall, but they are underrepresented in senior roles, as well as in specific academic subjects. Females are also less likely to stay in science throughout their lifetime than males. In contrast, individuals from lower socio-economic backgrounds are less likely than others to even enter scientific professions in the first place.

This complexity requires a range of multifaceted approaches. We need to promote educational opportunity – but also overcome the stumbling blocks to the appointment, development, and retention of a more globally representative workforce. The difficulties that one underrepresented group may face undoubtedly differ to those faced by another across educational and career trajectories. In this issue, we showcase an impressive range of initiatives that, in different ways, are making positive steps towards embracing difference, inclusivity, and diversity.

We begin this issue with an interview with Jon Lorsch, Director of the National Institute of General Medical Sciences, part of the National Institutes of Health. Here, we explore the Institute's commitment to developing our next generation of biomedical scientists. Ongoing initiatives are provided for school children through to students at undergraduate and postdoctoral levels, as well as for scientists working outside of academia.

We then consider the work of Dr John Monahan at the University of Alaska Fairbanks. The progression from high school to university has traditionally been a road less travelled in this rural Alaskan community. Dr Monahan provides involvement for high school students in STEM projects that also benefit the local community.

Dr Fern Tsien at Louisiana State University also supports the education of minority groups, from those in elementary school through to those in higher education. Focusing on health and basic sciences, her aim is to provide inspiring role models for females and underrepresented groups, as well as providing students with practical first-hand experience in science.

By providing insights into real-world scientific endeavours, as well as broadening students' horizons at an early stage in their education, Dr Monahan and Dr Tsien contribute towards diversifying our future scientific workforce. Dr Etta Kralovec at the University of Arizona, South, takes a different tack but with the

same aim. Dr Kralovec's work supports teachers in providing high-quality teaching in STEM subjects for middle and high school students in the Arizona borderlands, where previously, educational provision has been lacking.

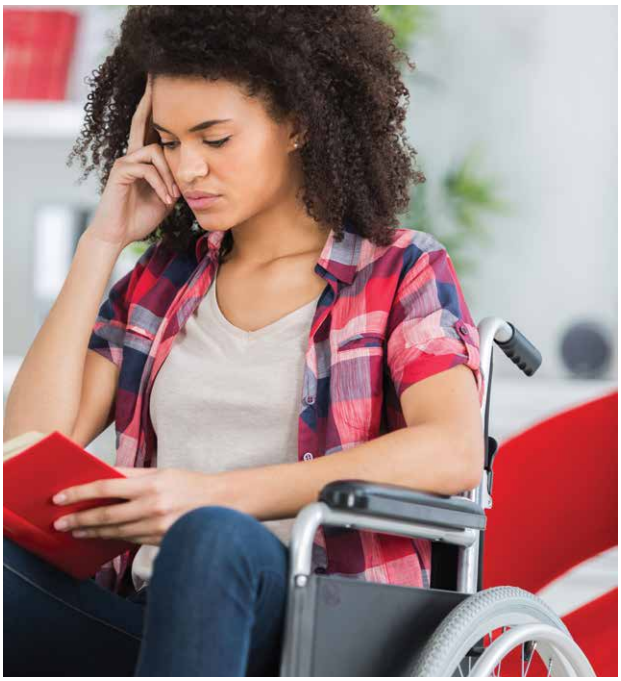
Dr Melanie van Stry, of Lane College, focuses on maximising the retention and achievement of students from underrepresented backgrounds studying chemistry and biology at degree level. Her work demonstrates the utility of novel pedagogical approaches in this context and she aims to extend these approaches to other scientific fields.

We then move on to the work of Dr Rodolfo Mendoza-Denton of the University of California, who is taking a closer look at the academic opportunities offered to students from different socioeconomic and racial backgrounds. Using a social psychological framework, he is exploring the factors that may help non-traditional students believe they can succeed in academia.

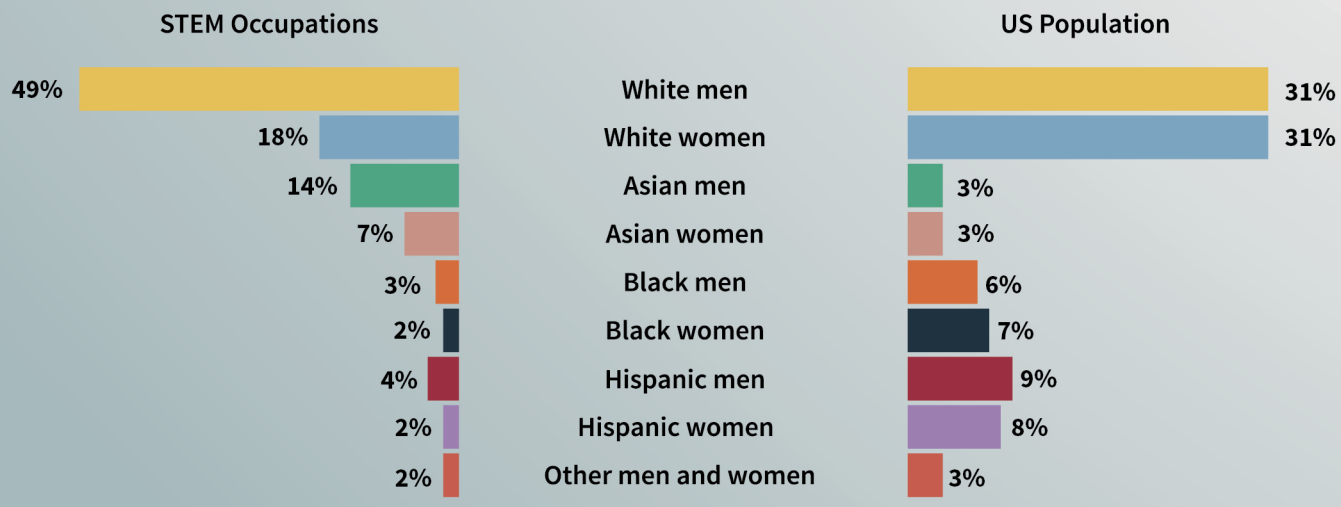
Drs Michelle Bower and Abigail Littlefield, of Landmark College, are working to create educational, mentorship, and employment opportunities for students in STEM subjects. Their work specifically focuses on students with learning disabilities, including those with dyslexia, autistic spectrum disorders, and attention deficit hyperactivity disorder.

It readily becomes apparent when considering the innovative work of Dr van Stry, Dr Mendoza, and Drs Bower and Littlefield, that promoting diversity in higher education requires innovation in how teaching and opportunities for learning are delivered, above and beyond making opportunities available for students to study in the first place.

Finally, we consider the importance of investing in and maintaining diversity of academic staff. Dr Suzanna Rose, of Florida International University, seeks to help overcome the difficulties faced by females and minorities in obtaining faculty positions within higher education. Dr Margaret Bailey, of Rochester Institute of Technology, is committed to identifying ways to retain females, particularly of colour and/or with disabilities, working in STEM subjects. The work of Dr Rose and Dr Bailey again emphasise the need for not only multifaceted, but concentrated and sustained efforts, towards achieving and maintaining diversity in our scientific workforce.

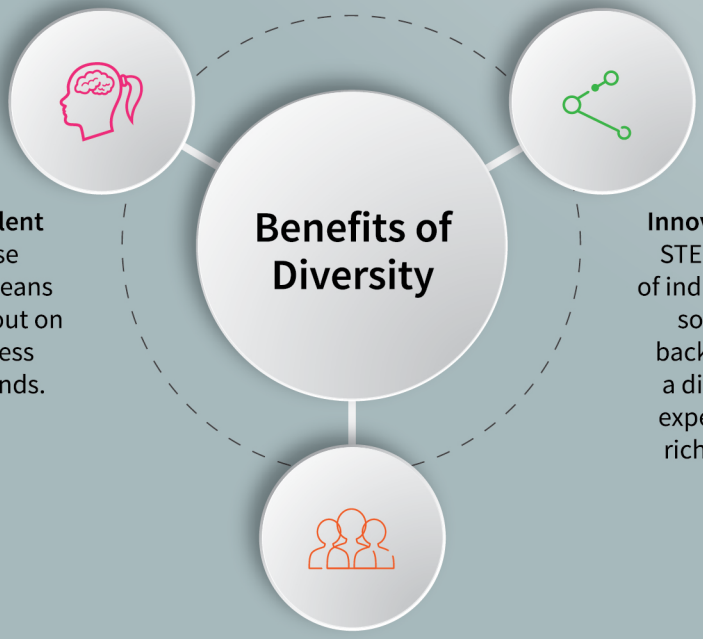


LACK OF DIVERSITY IN STEM OCCUPATIONS (USA, 2015)



Source: US National Science Foundation

WHY DIVERSITY MATTERS IN STEM



Identifying Top Talent
Failing to increase diversity in STEM means that society misses out on identifying countless bright scientific minds.

Innovation & Creativity
STEM teams made up of individuals from varied social and cultural backgrounds and with a diverse range of life experiences provide a richer mix of ideas to build upon.

Growing the STEM Workforce
If more underrepresented groups, such as women or those from minority backgrounds, are encouraged to pursue STEM careers, the STEM workforce will grow. This will help us to meet the ever-increasing demand for STEM professionals into the future.

NATIONAL INSTITUTE OF GENERAL MEDICAL SCIENCES: LEADING THE WAY IN STEM EDUCATION & TRAINING

Established in 1962, the National Institute of General Medical Sciences (NIGMS) is one of the 27 Centers, Institutes and Offices within the National Institutes of Health (NIH) – the primary medical research agency of the US Government.

In addition to supporting basic biomedical research, NIGMS provides leadership in training the next generation of scientists. To do so, NIGMS supports a broad range of science education, training, and career development programs for individuals and institutions.

In this exclusive interview, we had the opportunity to speak with Jon R. Lorsch, Director of NIGMS, who discusses the Institute's varied approaches towards fostering the best trained, most innovative, diverse, and productive biomedical research workforce possible.

NIGMS offers a wide range of education and training programs in the biomedical sciences. Shown above (from left to right) are: a high school student participating in a Science Education Partnership Award (SEPA) program, an undergraduate scholar in the Building Infrastructure Leading to Diversity (BUILD) program, a graduate student pursuing a dual MD/PhD degree with support from a predoctoral fellowship to promote diversity, a fellow in the NIGMS Postdoctoral Research Associate Training (PRAT) program, and a postdoctoral scientist supported by an NIH Pathway to Independence Award. Descriptions of all NIGMS education, training, and career development programs are available on the NIGMS website.

To start, please tell us about NIGMS's mission to foster the next generation of biomedical scientists.

Ensuring the vitality and continued productivity of the research enterprise is core to the mission of the National Institute of General Medical Sciences (NIGMS). To accomplish this goal, NIGMS sponsors training programs tailored for each stage of career development from undergraduate students through faculty members. The goal of all these efforts is to develop a diverse pool of well-trained scientists available to address the nation's biomedical research needs.

Young students in the Integrated Science Education Outreach (InSciEd Out) program in Rochester, Minnesota, learn about environmental science by studying zebrafish. Funded by a Science Education Partnership Award, InSciEd Out is a collaborative partnership designed to engage students and empower teachers through research-based, experiential, classroom learning. CREDIT: InSciEd Out

Is NIGMS involved in any initiatives to encourage school children to pursue careers in biomedical science?

Yes! We reach school children across the nation through the Science Education Partnership Award (SEPA) program. This program connects biomedical or clinical researchers with teachers and students in pre-kindergarten through grade 12. The interactive partnerships, along with special opportunities for students from underserved communities, form a pre-college pipeline to careers in biomedical, behavioural and clinical sciences.

SEPA also bolsters the understanding and appreciation of science, technology, engineering and mathematics (STEM) among young students. To do so, SEPA provides teachers with professional development in science content and teaching skills; funds health-related exhibits in museums and science centers; and supports the creation of educational tools that use technologies like virtual reality, 3D printing, wearable devices and interactive, online learning platforms.

'Striving to increase workplace diversity is not an empty slogan — it is a good business decision… Nonhomogeneous teams are simply smarter.'

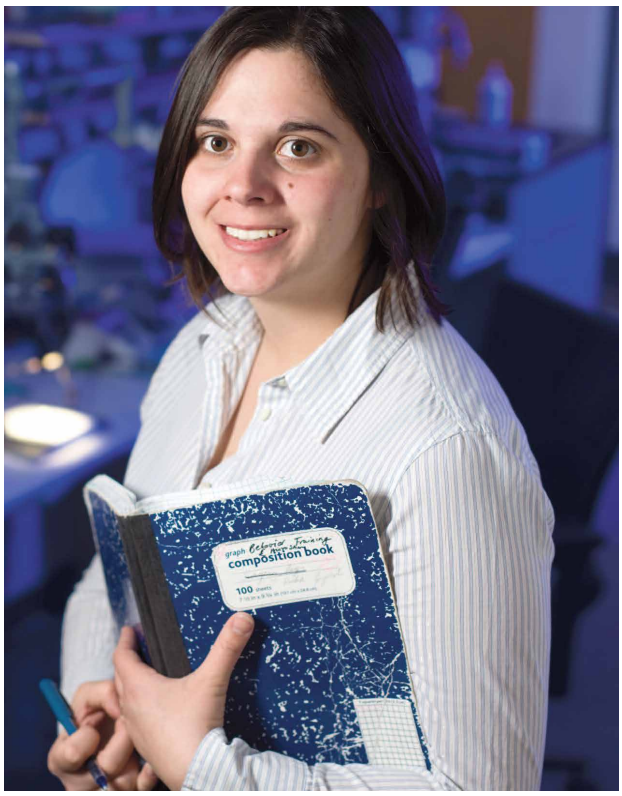
– David Rock and Heidi Grant, Why Diverse Teams Are Smarter, Harvard Business Review
Why Diverse Teams Are Smarter

Explain how NIGMS works towards achieving diversity and inclusion at undergraduate, graduate and postdoctoral levels, to ensure a diverse biomedical workforce in the future. How is this initiative important for meeting national research goals?

NIGMS firmly believes that our nation is best served by a research workforce that benefits from a rich diversity of perspectives, skills and experiences. Research on business productivity backs up this assertion. Multiple studies demonstrate that diversity within work teams enhances creativity, balances biases, promotes innovation and sharpens decision-making abilities.

Fostering a diverse and inclusive future workforce is a key priority for the Institute. Toward this end, NIGMS supports a broad collection of training and capacity-building programs designed to develop talented people from underrepresented populations. These programs provide many types of support, training and mentoring for students at multiple career stages. The programs operate at a variety of educational institutions across the country, including research-intensive universities, community colleges, undergraduate institutions, minority-serving institutions and medical schools. Some of the efforts, such as those that fall under the Institutional Development Award (IDeA) program, support students in 23 US states (and Puerto Rico) that historically have not received high levels of NIH funding.

Together, these programs aim to ensure we draw from the entire pool of talented individuals, bringing different aptitudes, skills and approaches to address complex scientific problems. By training and retaining a diverse and inclusive workforce, we will maximise our opportunities to advance biomedical science, improve our nation's health and maintain its global competitiveness.



Cara Altimus was supported by NIGMS as a PhD student at Johns Hopkins University. She is now associate director at the Center for Strategic Philanthropy at the Milken Institute. Altimus uses her expertise in neuroscience to monitor research on many diseases and to advise individuals and foundations seeking to donate to biomedical science. CREDIT: Keith Weller

NIGMS supports almost half of all NIH-funded PhD students in training programs at colleges, universities and medical centres in the US. Please tell us about the Institute's focus on PhD student development.

The primary objective of training PhD students is to develop future generations of responsible, well-trained, rigorous scientists who will advance biomedical and behavioural research. Since its establishment in 1962, NIGMS has played a leadership role in this endeavour. We are currently focused on supporting needed updates and improvements to graduate-level education, which has remained largely unchanged for decades.

Only a fraction of PhD students will go on to achieve tenure-track positions. How does NIGMS adapt its training programs and initiatives to provide the foundation for a wide variety of scientific career paths?

As the demand for biomedical scientists expands beyond academia, many graduate trainees pursue careers in industry, business, education, communication, science policy, government, law or other fields. To ensure they are equipped to play important roles in these professions, we aim to shift the focus of NIGMS training programs to place more emphasis on broad-based skills that facilitate success in a range of occupations. Examples of such transferrable skills include analytical thinking, data analysis, clear writing, oral presentation skills, project management, the ability to work effectively in diverse teams,

'Not all trainees choose an academic path today, nor should they. In an increasingly technical world, a variety of professions benefit from well-trained scientists who address critical societal needs. Many trainees possess the skills and passion to contribute their scientific expertise to the worlds of business, policy, teaching or writing.'

– *Investing in the Future*: National Institute of General Medical Sciences Strategic Plan for Biomedical and Behavioral Research Training 2011: IDeA Networks of Biomedical Research Excellence

and character traits such as creativity, curiosity and resilience. NIGMS promotes the use of individual development plans to help trainees plan for their future careers. The Institute also encourages efforts by scientific societies, institutions and mentors to make students aware of the range of professions that can benefit from a scientific perspective and honed research skills. In other words, by providing rigorous intellectual experiences, cultivating transferrable skills and encouraging self-awareness, NIGMS training programs are preparing trainees to make valuable contributions not only in academia, but also in boardrooms, classrooms and courtrooms around the nation.

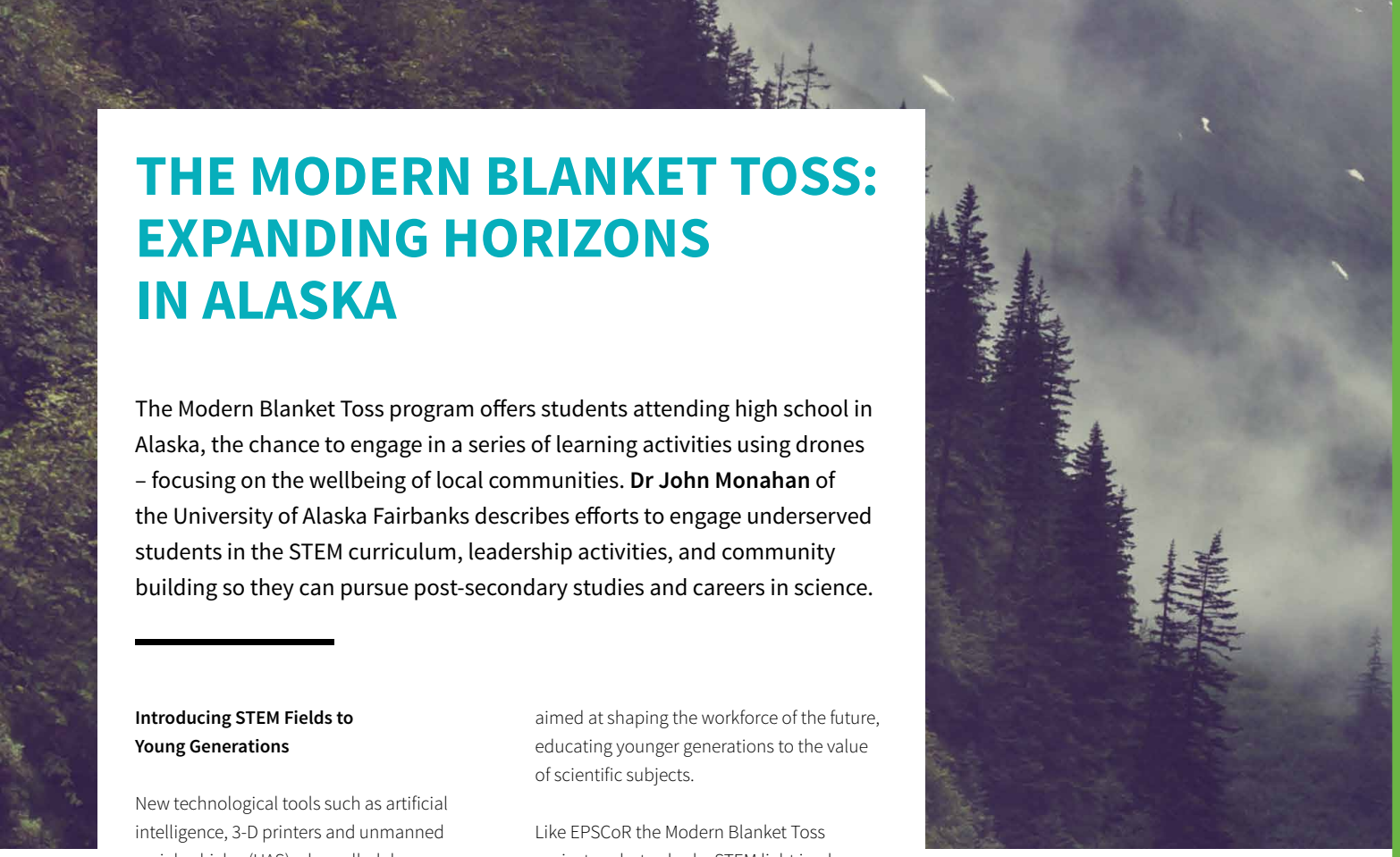
Finally, what does NIGMS do to ensure that colleges and universities monitor, measure and continuously improve the quality of their training efforts for students and postdocs?

We use a variety of methods to evaluate the success of our training efforts. We fund training grants for a limited time (usually five years). Each year, the director of the training program submits a progress report that describes the research and professional activities of his/her students. In addition, many programs require an annual evaluation to assess how each training grant is contributing to an overarching goal – say, increasing the number of students from underrepresented groups who complete a PhD degree. Some programs, such as the IDeA Networks of Biomedical Research Excellence require an external advisory committee and an external evaluator to regularly monitor and assess success of the program.

To continue the training program after the initial grant period, the director must reapply for funding. This re-application process includes a rigorous review by a panel of experts, including experienced scientific mentors and well-regarded researchers. Periodically, reports on long-term evaluations of specific training programs are issued by the NIGMS Office of Program Planning, Analysis, and Evaluation (see examples at https://www.nigms.nih.gov/about/opae/Pages/reports.aspx) and the National Academy of Sciences (https://www.nap.edu/collection/43/higher-education and https://www.nap.edu/read/18384/chapter/1).

As I mentioned above, NIGMS is also actively engaged in improving and modernising graduate education in the biomedical sciences.

www.nigms.nih.gov



THE MODERN BLANKET TOSS: EXPANDING HORIZONS IN ALASKA

The Modern Blanket Toss program offers students attending high school in Alaska, the chance to engage in a series of learning activities using drones – focusing on the wellbeing of local communities. **Dr John Monahan** of the University of Alaska Fairbanks describes efforts to engage underserved students in the STEM curriculum, leadership activities, and community building so they can pursue post-secondary studies and careers in science.

Introducing STEM Fields to Young Generations

New technological tools such as artificial intelligence, 3-D printers and unmanned aerial vehicles (UAS), also called drones, are gradually affecting societies worldwide. As technology becomes increasingly complex, finding engaging ways of introducing science, technology, engineering, and mathematics (STEM) to younger generations is of key importance to providing the presence of a technically skilled workforce in years to come.

This is particularly and practically true for groups that tend to be underrepresented in STEM fields, such as women and ethnic minorities. Numerous programs worldwide are trying to increase underrepresented students' interest in science, with the hope that this will bring greater diversity within fields that might seem intimidating or hard to approach.

The aim of these programs is to introduce particular fields of science in engaging ways to young people who might otherwise never be exposed to them with the hope that this will stimulate their desire to expand their knowledge of STEM-related subjects. The Experimental Program to Stimulate Competitive Research (EPSCoR) is one of the social institutions trying to strengthen STEM-related skills at national and global levels, broadening the participation of different cultural groups in scientific activities.

Establishing partnerships with governments, schools, higher education providers, and industry experts, EPSCoR develops programs aimed at shaping the workforce of the future, educating younger generations to the value of scientific subjects.

Like EPSCoR the Modern Blanket Toss project seeks to shed a STEM light in places where research shows it shines the least – among underserved populations in remote communities. Not by removing the students from their communities, but by providing STEM and leadership tools they can apply in their own backyards.

Increasing STEM Interest in Alaskan Students

High school students in rural Alaska face numerous challenges on their path to college and in their pursuit of STEM careers. Many of these students are Alaska natives, an underrepresented minority, living in impoverished communities that are often hard to access by road.

As most of their family members never attended college and come from low-income backgrounds, they tend to be less aware or motivated to pursue higher education. Local Alaskan high schools also sometimes lack advanced equipment and resources, making it harder for these students to get the chance to experiment with relevant technology.

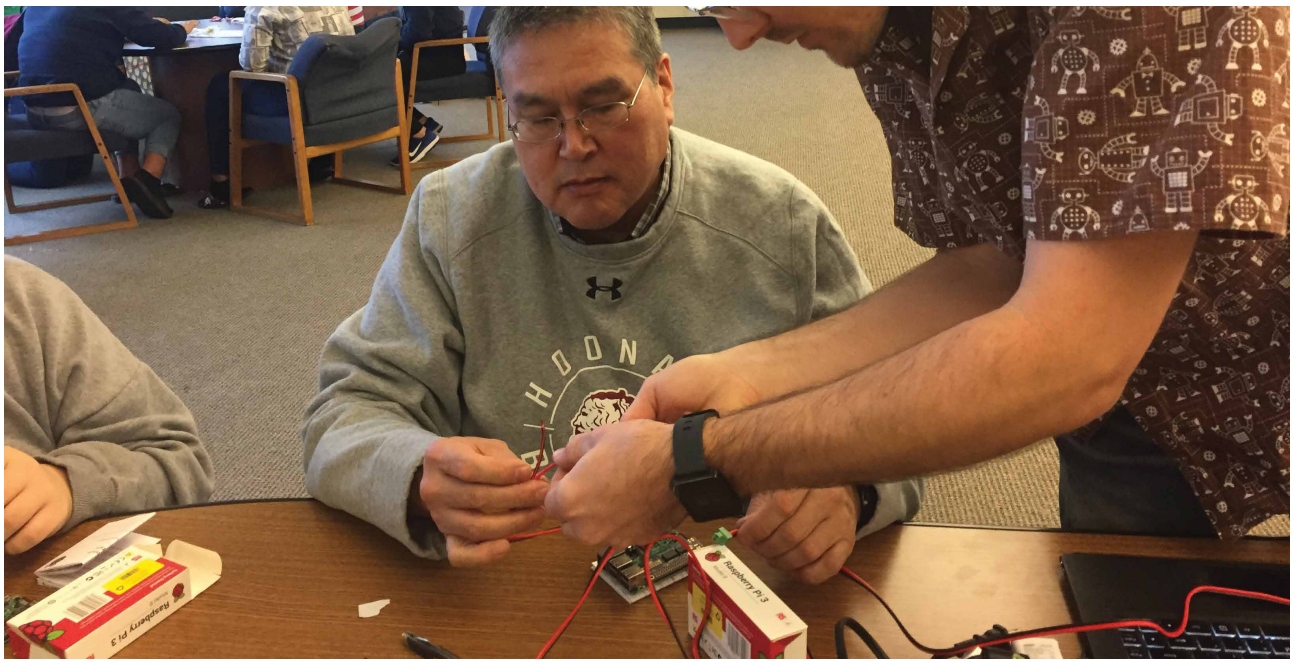
All these factors combine to make it difficult for many students living in rural areas in Alaska to pursue further education, ultimately limiting their possibilities in STEM-related careers. The Upward Bound program hopes to change this and has already run several initiatives aimed at increasing the rates of college applications from low-income

students, which included tutoring sessions, summer projects, and other assistance during the academic year.

The program recruits these students to learn new habits for study and scientific thinking, which makes it possible for students to understand and function in the academic worlds of post-secondary education. Otherwise the gap from the village to the university would be too wide for many of these students to cross.

So far, it has already achieved considerable results. Since 2000, 41% of the underprivileged students who took part in the initiatives organised by the program pursued further education, more than five times the proportion observed in other students who did not participate.

‘We named this project after the Native tradition of the Blanket Toss, which enabled people to expand their horizons beyond their immediate surroundings. We want this project to do the same thing.’



The Modern Blanket Toss

The Modern Blanket Toss is a project devised by EPSCoR in collaboration with the Upward Bound program at the University of Alaska Fairbanks (UAF), with the mission of helping students living in rural areas of Alaska to develop an interest and skills in STEM fields, while also benefitting local communities.

The five schools participating are situated in the communities of Shishmaref, Bethel, Chefornak, Nikiski, and Seward. Dr John Monahan, Director of the Upward Bound program and Principal Investigator of the project, said, ‘we named this project after the Alaskan Native tradition of the Blanket Toss, which enabled people to expand their horizons beyond their immediate surroundings. We want this project to do the same thing – literally, by giving students a bird’s eye view of their communities, and figuratively, by exciting them about college and STEM careers.’ The project ‘lifts’ students’ awareness of their local surroundings through science and community projects through leadership development.

During the program, the students participate in learning activities using Unmanned Aerial Vehicles, commonly known as drones, and Geographic Information Systems (GIS) technologies. Rural Alaska is an ideal location for this project, because of its educational challenges, as well as its substantial level of expertise in the field of drone technology.

Being a large state affected by harsh weather conditions, where 82% of local centres are not served by roads, Alaskan communities can truly benefit from drones and advanced GPS technology, that could be used to map territories that are hard to access, or to monitor community environmental conditions that might threaten safety or quality of life.

This is particularly true for the areas where the program takes place, that are surrounded by wilderness and are difficult to explore. In the summer, all students who take part in the program receive immersive training at the UAF campus, on using drones and attend leadership classes about pursuing careers in science and research. The course includes teaching the students about drones, geospatial cognition, GIS, and other associated scientific concepts, as well as leadership and hands-on experiences using the technologies available at UAF.

Subsequently, students return to their communities, attending course-related learning activities in school and performing experiments with drones and GIS devices, that include mapping, simulated search-and-rescues, aerial photography, weather studies, and other exercises designed to increase STEM awareness and skills.

In addition to their normal lessons at their local school, the program coordinators teach the students about drones and GIS technology, as well as basic maths and science, either in person or through video conferences.

Applying their Skills to Community Projects

The Modern Blanket Toss program incorporates very strong hands-on components. Throughout the course the students take part in various practical activities using drones and GPS software. Towards the end of the year, every school is assigned a mapping project designed to benefit local Alaskan communities as part of the leadership training for students. Students learn to listen and research the needs of their own communities through elders and community organisations. They become ‘part of the solution’ through this program that teaches active citizenship.

‘In the Modern Blanket Toss students first learned the skills needed to fly an unmanned aerial system and process data, before approaching the unique projects that each community felt was important and possible to address with such a system,’ describes

Dr Monahan. When completing these leadership community projects, students are asked to apply the knowledge they acquired to a broad variety of tasks, ranging from examining landfill locations, to mapping and recording street names, or tracking changes in local sea ice.

'Each project was unique to the community involved and each used the skills taught,' says Dr Monahan. 'In Bethel, students worked to map open holes on the river ice. In Seward, students worked to map areas that were inundated by seasonal floods. In Shishmaref, students mapped the erosion of the beaches. Each project is different, but all students followed a process to understand community issues and utilise the technology integral to addressing the problem.'

All the projects provide students with the chance to learn and lead in their own community building confidence and resiliency among students that prepares them for college. The students are encouraged to share their results with each other and with their coordinators, to exercise their communication and leadership skills, while experiencing what it means to feel part of a larger learning community.

Once the mapping projects are complete, they are asked to present their results at community meetings and events, including a workshop in the final summer of the program, where results are showcased for an audience of nationwide educators. Students are seen and see themselves as young leaders who help their neighbours and families through STEM skills.

The Project's Accomplishments

So far, the Modern Blanket Toss project has achieved remarkable results, with local coordinators feeling they acquired considerable knowledge about drones and GIS software, potentially improving their STEM instruction and providing extensive help for future community projects. Overall, students who participated were also very satisfied with the program and were excited to learn about drones and GPS technologies.

They showed appreciation for the practical aspect of the course, both in terms of the experience with flying drones and with the mapping applications. Students also felt that they had made important connections with peers, teachers and coordinators, that boosted their enthusiasm and positive attitude about scientific collaborations.

Most students who participated in the program felt it improved their communication skills, their knowledge of the STEM content areas and their understanding of scientific practices. The program, however, did not always run smoothly, and program leaders found they had to deal with unique challenges, such as the harsh Alaskan weather, the speed at which the technology used became out-dated, and the inaccessibility via internet and communication of the rural areas in which some of the schools were situated.

However, the positive feedback received from those who took part encouraged the program leaders to expand and improve the project over time. And the students grew more resilient in their growth mindsets willing to persevere and learn from mistakes.

The T3 Project – a Brand New Program for Alaskan Youths

The Upward Bound program at UAF is now collaborating with EPSCoR on a new project founded by the US National Science Foundation, that is also aimed at promoting STEM-skills among young generations in rural areas of Alaska.

The new education quest, called the 'Teaching through Technologies' (T3) Alliance' program, will recruit instructors and students from several remote communities in Alaska and support them, both online and in person, in adopting new curricula including scientific training and practical use of emerging technologies. The program will particularly focus on UAS, 3-D printers and small computer like code-able digital devices called Raspberry Pis.

Students who take part will also receive training in STEM communication and leadership, applying their newly acquired skills to solve issues relevant to the local community.

'The 36 sites in the T3 Alliance program across the 'lower 48' have a wide variety of geographic, environmental and cultural conditions that make it difficult to use a "one size fits all" model for community projects,' said Dr Monahan. 'Early on in the program we will teach the process of leadership and design thinking to identify and prototype solutions that meet the unique needs of their community.' The curriculum will also include the key component of teaching growth mindset to embed resiliency in the face of setbacks and embracing mistakes as new learning opportunities.

Practical activities could include building a sensor game using Scratch and Python coding language in the Raspberry Pi, or designing and printing 3D objects integrating Raspberry Pi sensor components. Similar to the Modern Blanket Toss program, this new project was designed to help young underrepresented youth gain greater knowledge of new technologies, while also encouraging them to apply their scientific skills in real-life scenarios that are meaningful to their community.

The projects developed as part of the Upward Bound program of UAF are a perfect example of how the right academic initiatives could open greater possibilities for young people who are part of underrepresented minorities, encouraging them to pursue further education in STEM-related subjects and hence promoting a more diverse skilled workforce for the future.

The leadership and community building aspects of the project further prepares students for leadership roles in STEM careers to apply new tools to the benefit of the organisation and the community as a whole.

Meet the researcher

Dr John D Monahan
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Dr John Monahan is the current director of Upward Bound courses at the University of Alaska. After completing a BA in Business at Rockhurst College in Kansas and an MS in Cultural Education at Kansas State University, Dr Monahan began his extensive career in education. He has worked within a broad range of academic settings, teaching Education Leadership at the University of Alaska Anchorage, previously covering other roles such as Superintendent at Fairbanks North Star Borough, as well as principal and teacher at a number of schools in Alaska and Kansas. Dr Monahan's career has primarily focused on the administration of academic institutions and on promoting the introduction of technology-assisted instruction. Prior to his return to the University of Alaska, he also worked for three years with Apple, coordinating the Alaska One-to-One project, which was aimed at administering computers and technological tools to students and teachers at universities. Over the past decade, he has covered different roles at Alaska University and has travelled around the country, working closely with students, teachers, and administrators. Dr Monahan has recently been working on a project called the 'Modern Blanket Toss', using drones to introduce technology to First Nation students, while broadening their understanding of the local community.

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UNIVERSITY of ALASKA
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ROADMAP FOR SUCCESS: INCREASING DIVERSITY IN THE BIOLOGICAL SCIENCES

Historically, there has been a disparity between the demographics found in the broader population and in academia. Women and many minority groups are underrepresented in science careers. **Dr Fern Tsien** at Louisiana State University is directing educational programs in the New Orleans area aimed at improving this disparity, supporting underrepresented groups throughout their education, from elementary school through to post-graduate training.

Despite pushes for diversity over the past two decades, women and minorities are still underrepresented in the sciences. Many factors contribute to this phenomenon, including historical disparity in career opportunities offered to minorities, lack of awareness of underrepresented minority science role models, and poor access to quality early science education in underprivileged schools and communities. Everyone benefits from diversity in science – modern science is a collaborative effort, and the most powerful scientific insights often arise from interactions between scientists with unique perspectives working together. Many of the challenges humanity will face over the coming decades will demand interdisciplinary teams of scientists with a mixture of backgrounds and viewpoints, each bringing new ideas to the table.

One of the foremost missions in modern education is finding ways to increase female and underrepresented minority inclusion, participation, and retention in the sciences. Dr Fern Tsien works with the faculty of Louisiana State University in New Orleans (LSUHSC-NO) and teachers in Louisiana schools to help bring more minorities to the table in biological and health sciences. She states that, 'my goal is to increase the number of underrepresented minorities pursuing careers in the health and basic sciences.'

Starting Early for Scientific Success

To increase science participation at the college level, it is critical that children are granted access to high quality science programs early in their education, to both spark interest and create awareness of science as a viable career path. In 2003, the Louisiana State University Health Sciences Center (LSUHSC) began the Science Youth Initiative (SYI) in New Orleans public schools. Today, the program continues with funding from local and federal agencies, including the Entergy Foundation and the National Science Foundation.

The program helps to increase diversity, interest, and involvement in basic biology and health science subjects at the elementary, middle, and high school levels (K-12) by introducing students to diverse female scientists and underrepresented minority role models. The program makes science easier to understand through hands on activities, helps students improve their academic achievements, increases awareness of and access to potential science careers, and engages in community science education. Dr Tsien began directing the program in 2009, and under her leadership it has extended to reach hundreds more students throughout New Orleans.

The SYI program has three components aimed at reaching students at different age levels and across multiple biology and health science tracts. Starting in the fourth grade, the LSUHSC/New Orleans Schools Science Partnership Program for Elementary Schools brings LSUHSC faculty and trainees into the classroom to engage students in curriculum related experiments, such as extracting genetic material from strawberries.

The program is currently active in eight New Orleans elementary schools, and has also produced educational videos of the material to help broaden the reach of their work. The group is working to translate these videos into Spanish to reach an even wider audience of young learners. Since the program's initiation in 2006, academic performance in the sciences and science standardised test scores have risen for over 700 SYI students and counting.

The next stage of the SYI program, The LSUHSC Hands-on Workshops for Middle and High Schools, was founded in 2009, and works to build on the foundation of the elementary

‘My research goal is to increase the number of underrepresented minorities pursuing careers in the health and basic sciences.’

school curriculum to continue to fuel student interest in science education and careers. The day-long workshops offer students in Advanced Placement and Honours Biology courses the opportunity to tour LSUHSC facilities, meet research scientists, and conduct experiments in exciting and relevant topics, such as forensics and cancer research.

The workshops introduce students to the wide variety of careers with a base in the biological and health sciences, ranging from medical practice, to basic research, to public health. Students are also given access to educational videos that reinforce and build upon the information they gained during their visit to LSUHSC. Over 2000 students have participated in workshops so far, and many continue on to participate in the final phase of the program.

The third component of the SYI program, The Summer Internship Program for High School Students, began in 2003 and serves as the culmination of the SYI school-age biological sciences education progression. The program provides support for internships for high school students to work in laboratories with LSUHSC faculty members for eight weeks over the summer. Qualifying students earn stipends while they gain hands on experience with research and present their findings at a research symposium at the end of the summer. As part of their summer experience, the students participate in workshops to learn about topics such as laboratory safety, responsible research conduct, science communication, writing resumes, applying to college, networking with scientists, and science careers available to them.

Many continue working into the following school year and beyond with their mentors, attending scientific conferences or publishing in scientific journals. Students receive letters of recommendation and personalised support as they apply to universities to continue their science education. Over 160 high school students have been accepted into the program so far, and many alumni have continued on to university college study and graduate programs in the sciences.

Cultivating Diversity in Research

Dr Tsien’s work with underrepresented students extends to college undergraduates. In 2014 she secured a grant to direct a Research Experiences for Undergraduates (REU) program at LSUHSC, now part of a broad network of REU opportunities funded by the National Science Foundation in the United States. Like SYI’s summer opportunities for high school students, the REU provides funding and mentorship for undergraduates in science fields who are interested in gaining research experience that they can carry into graduate programs and research careers.

REU internships provide students with hard research skills, as well as structured professional development and science communication coaching. The program is designed to help prepare undergraduate students for the unique rigors of pursuing graduate education in the sciences, and provide a foundation of effective working skills that will benefit them throughout their careers. The overarching goal of the REU program is to build confidence and scientific skillsets, such that students who start the program as dependent apprentices leave as independent researchers, capable of forming their own hypotheses and carrying out their own research.

LSUHSC places a heavy emphasis on including historically underrepresented groups in their REU program, particularly African American/Black, Hispanic/Latino, and American Indian (Native American) students. In the United States, these three groups form approximately a third (29.8%) of the population, yet comprise less than 5% of the tenure-track professors in the biological sciences.

In LSUHSC’s immediate community of New Orleans, the population is 60.1% African American/Black, 5% Hispanic/Latino, and 0.3% American Indian, so the REU program

focuses efforts on recruiting local students, including those that have participated in the SYI before college. Further, Dr Tsien's program partners with Louisiana's Historically Black Colleges and Universities, along with other local colleges and universities. The program also leverages collaborative agreements with other universities around the United States and its territories to find diverse students at colleges around the nation with an interest in biological research. Along with underrepresented minorities, the program seeks to include women, non-traditional students, students from rural communities, and first-generation college students.

The Research Experiences for Undergraduates at LSUHSC focuses on genetic and biochemical mechanisms. Proficiency in genetics and biochemistry concepts and laboratory techniques are central to success in biological science research, and the program offers comprehensive training in current methodologies, hypothesis driven problem solving, data analysis, and communicating findings to the research community in a professional manner. In addition to these 'hard' science skills, students are provided guidance in 'soft' skills that are critical to success in the sciences, such as time management, teamwork, communicating science, and overcoming adversity in the scientific community.

While building critical professional skills is an important component of the REU, students' primary goal during their summer at LSUHSC is to contribute something new to our understanding of genetic and biochemical processes. Each student is partnered with an LSUHSC faculty member with whom they collaborate on a project for the summer. They learn how to design experiments using the scientific method, read and review current scientific literature on their project, and utilise the institution's extensive research facilities and equipment to apply state-of-the-art techniques to their experiments.

Students engage in cutting edge research, seminars, and workshops, as well as participating in community outreach education events. Through organised social events, students begin to build a network of scientific peers and mentors, forming supportive relationships that will bolster them throughout their scientific careers.

Finally, students are given personalised mentoring and professional development support, providing career counselling and advice, help with graduate school admissions, and recommendation letters. The program aims to recruit students early in their college careers so that the impact of academic and career counselling guidance the REU offers can be maximised through the course of their college education, setting them up for graduate success.

LSUHSC offers nearly numerous research possibilities, with labs working with organisms ranging from single celled bacteria to mammalian cells and tissues from organisms including humans and non-human primates. While in pursuit of their research questions, REU students learn cutting-edge methods, such as bioinformatics, genome editing, microscopy, histology, and advanced genetic protocols. Further, they learn how to analyse the data they collect and distil it into meaningful knowledge.

As a final step, at the end of the summer students present their findings at a scientist-reviewed conference, honing the skill of professional science communication that is so critical to long term academic success. Program alumni have received additional NSF funding to support their presentation of their research at the NSF Council of Undergraduate Research Conference in the Washington, DC area, and other scientific meetings.

From Strength to Strength

More than 379 college students have participated in the LSUHSC Summer Research Internship thus far since 2003. Since the debut of the LSUHSC-REU program three years ago, 41 underrepresented minority undergraduate students have completed the summer program. The program has offered many students from underrepresented groups the opportunity to take the first steps into blossoming research careers, supported by a team of dedicated mentors and enthusiastic peers. Of the first 41 students, 74% were African American/Black and 23% Hispanic/Latino, 64% female, with 20 first-generation college students, one non-traditional student in their 50s, and a student with a disability.

These students represent great strides in increasing diversity in the biology workforce, as alumni from the program have already begun to be admitted into graduate schools, along with presenting their work at national science conferences and submitting manuscripts for publication for peer-reviewed journals. During this short time, applications to the program have roughly doubled each year. Dr Tsien has also been granted supplemental funding from the NSF, which has allowed the REU program to take on an additional college student each summer, as well as additional SYI high school students. This grant also provides for the training of high school science teachers to serve in New Orleans school districts.

Beyond touching the lives of students in the SYI and REU programs, numerous community outreach events hosted by LSUHSC in collaboration with program students have occurred, bringing science education outside the classroom and benefiting the broader population. 'Medical and graduate students, residents, and post-doctoral fellows learn how to teach health sciences to the community through these programs,' says Dr Tsien. 'Teaching to the lay public is a necessary skill for future health care professionals and research scientists.'

Continuing Opportunity

The next logical step in the educational roadmap is increasing opportunities for students following college graduation, particularly students that are not immediately accepted into graduate programs. Dr Tsien explains that, 'not all college graduates are immediately accepted into graduate or medical school and may need additional resources to make them more competitive when applying to advanced academic programs.'

Recently, Dr Tsien and her colleagues at LSUHSC and Moffitt Cancer Centre in Tampa, Florida have received funding from the National Institutes of Health's (NIH) National Cancer Institute (NCI) for cancer research opportunities for underrepresented minority undergraduates, medical students, and junior faculty. Also she and her LSUHSC colleagues have received for the Post-Baccalaureate Research Education Program (PREP) for underrepresented minority students to work on professional and academic development during a gap year between undergraduate and graduate studies. Dr Tsien hopes the PREP will help enhance these students' opportunities for success in the sciences, and help prepare them for the rigors of graduate school.

Meet the researcher

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Dr Fern Tsien is an Asian/Hispanic/Latina American researcher and educator who began her educational career at Tulane University, New Orleans, LA, graduating with a double major in Biology and Studio Arts in 1989. She earned her PhD in Human Genetics from Tulane in 2002, specialising in epigenetics and cytogenetics. She joined the faculty of Louisiana State University Health Sciences Center in New Orleans in 2003, where she currently serves as a Tenured Associate Professor in the Department of Genetics. Her research illuminates the genetics of chromatin instability in cancer and congenital hearing loss in founder populations. She is dedicated to increasing diversity in the sciences, and currently serves as the Director of the New Orleans Schools Partnership, Hands-on Genetics and Health Education Workshop, Science Youth Initiative, and Research Experiences for Undergraduates (REU) Programs, and as Co-Director of the Summer Research Internship Program, and Postbaccalaureate Research Education Program (PREP). These programs work to make science education and careers more accessible to minority and disadvantaged students of all ages, both in New Orleans and throughout the United States.

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LSUHealthNewOrleans
HEALTH SCIENCES CENTER

INSPIRING SCIENCE TEACHERS IN THE ARIZONA BORDERLANDS

Recruiting and retaining high quality STEM educators in high schools can be a struggle, and even more so in under-served communities of the United States, such as the school districts that fall along the US/Mexico border. **Professor Etta Kralovec** at The University of Arizona, South, is pioneering a contextualised approach to teacher preparation that is transforming science and mathematics education in this border region.

In an increasingly technology driven world, science, technology, engineering, and mathematics (STEM) education is more important than ever and engaging tomorrows STEM experts in these topics early in their schooling is critical for ensuring a capable workforce in the future. Despite this need, many schools within the United States struggle to provide high quality STEM education to their young students.

STEM education along the border between the United States and Mexico can be particularly challenging, as teachers are working in small communities with little or no access to STEM enrichment and uneven internet access. They are doing their best to support binational classrooms with limited support and resources. The Noyce Border Scholars Program (NBS), headed by Kralovec at the University of Arizona, South (UAS), works to prepare secondary school STEM teachers to work in the high-need schools on the Arizona border.

Formed out of a partnership between faculty at the UAS, Cochise College, and the University of Arizona pioneering research and educational facility, Biosphere 2, the program recruits STEM teachers into the UAS Masters in Education (MEd) program. The program provides specialised education with continued classroom and professional development support – preparing its scholars to provide top notch STEM education to middle and high school students in the Arizona borderlands.

Ready for the Classroom

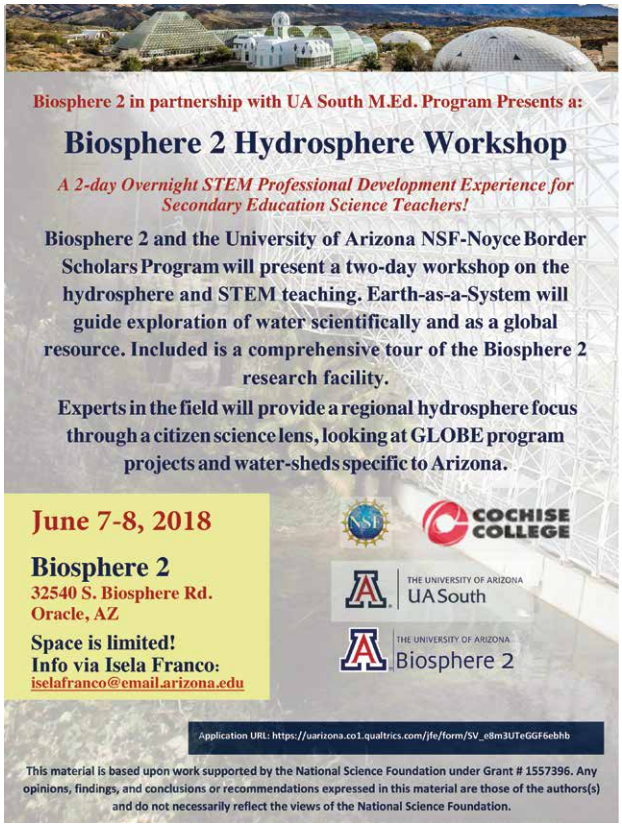
In the Noyce Border Scholars program, Kralovec has reimagined the Masters of Education (MEd) program at UAS to provide context-specific teacher preparation for STEM teachers in border schools. The new teacher intern certification track encourages a strong sense of community among the future educators and provides extensive mentorship and guidance for continuous improvement.

Scholars are evaluated frequently using classroom observation and data collection through surveys to inform coaching and help keep teachers steadily improving and gaining confidence in the classroom. A participant describes how: 'I love this program. Some of the other teachers at my school are working on their master's degree and I feel bad for them for how little support they have. I feel very supported with this program and because I do, I feel like I am a better teacher.'

In their second year of teaching, Noyce scholars conduct their own research projects in their classrooms. These participant action research projects are aimed at increasing beginning teachers' ability to conduct research in their classrooms. Often using student voice methodology, this research increases new teachers' understandings of the educational issues facing their students.

Recent research topics have included measuring student engagement and academic achievement in STEM subjects, engagement in Earth Science classrooms and student-designed biology inquiry activities. These projects are developing an understanding in new teachers of how students perceive their academic achievement, of the importance of building personal relationships with all students, and strategies to get more students involved in science. The work of these Noyce scholars will further expand the impact of this program, providing valuable insights that can improve STEM education in border schools around the world.

‘The aspect of multiculturalism and equity is the most exciting and rewarding aspect of this program. It is incredible to be able to hear others’ ideas and exchange ideas on how to increase these types of discussion in our own classrooms,’ MEd graduate.



Educating the Teachers

The Noyce Border Scholars participate in Teacher Education Seminar (TES) sessions, a monthly seminar series for new teachers, is designed to help them tackle common teaching challenges unique to teaching in the borderlands. Topics have ranged from building an ideal classroom climate, to cultural sensitivity, to building better teacher student relationships, to understanding the impacts of migration on education. ‘The aspect of multiculturalism and equity is the most exciting and rewarding aspect of this program. It is incredible to be able to hear others’ ideas and exchange ideas on how to increase these types of discussions in our own classrooms,’ says an MEd graduate.

The program has been highly popular, with increased enrolment in the past academic year requiring an expansion to a second location. STEM enrichment and special content for the NBS scholars remains localised in Cochise County, while additional TES seminars have been started in neighbouring Pima County. Another participating teacher describes how, ‘this program has offered me an abundance of knowledge and skills that have impacted my teaching in a positive way. The program has clarified certain questions I had about teaching and multiculturalism and has helped me understand my students in a better way.’

Once a year, a day-long symposium brings international education experts to Cochise County, engaging community stakeholders, regional teachers and the public in conversations relevant to border education. The Living and Learning the Border Symposium enjoyed its seventh year this February, where the content focused on engaging Latino Youth in the classroom.

Finding the Right Teachers

Representation matters, particularly in STEM fields, where young people from minority communities are less likely to encounter depictions of scientists that look like them in the popular media. One of the goals of Dr Kralovec’s work is to recruit highly qualified, underrepresented minority STEM teachers in border schools.

To accomplish this aim, the program is targeting local residents and military personnel that are already residents of border communities. In October 2017 the group developed a strategic marketing plan to support the recruitment of teachers in their target demographics. The NBS team advertises on job finding websites and attends state-wide career and educational fairs.

Marketing efforts have increased the number of applicants, but the greatest source of potential candidates has been word of mouth within the partner school districts. School district administrators have been the hub of recruiting activity, referring qualified applicants and helping the NBS team to identify which candidates might make the best match for the program.

These regional efforts have helped to match capable new teachers back into these school districts, further motivating the process. A school administrator describes the enjoyment of watching these new teachers catch on, ‘we have been very pleased with the teachers we receive from UA South. They have been energetic, very coachable and really like the kids. They come in very unprepared, due to their lack of experience, but they catch on quickly.’

A Diverse Range of Scientific Learning Opportunities

The NBS program provides professional development for scholars during their first two years of teaching through a collaboration with the UA Biosphere 2 research facility and STEM content specialists from Cochise College. These activities, led by co-primary investigators Dr Bonine of the UA Biosphere 2 and Dr Kristy Ritter of Cochise College, provide the new teachers with continued learning and novel approaches to pedagogical content knowledge and student engagement, equipping them with new tools and strategies to implement in their classrooms. Additional program partners have offered even more development opportunities to the scholars, providing a broad range of content that will enrich borderland classrooms, especially in the area of citizen science.

Under the leadership of Dr Bonine, Biosphere 2 has provided program enrichment around school gardens and resource management specific to the region. Sessions have been offered on Exploring School Gardens and Agrivoltaics and Aquaphonics and have directed the new teachers on how to leverage school and community gardens as educational tools. The scholars toured community garden sites and were provided with extensive resources on using gardens to engage students. (BIO2) This work has been further supported through a partnership with the UA Department of Agriculture’s Cooperative Extension. This

has provided content on the logistical considerations for starting a school garden and resources to help secure garden funding and facilitate community engagement in Biosphere 2 summer experiences, that are shaped by teacher interest, with a continued dedication to helping students connect with nature. This program also offers scholars an immersive, overnight experience at Biosphere 2.

Dr Ritter, spearheads the CirculoSOAZ Borderlands Math Teacher Circles, held seven times a year to provide scholars specialising in mathematics with professional development opportunities. She has been contributing extensive content to the blossoming program that is already having a powerful impact on the borderlands teaching community. The sessions are well attended, attracting math teachers from both sides of the border to form a unique multi-national group dedicated to improving mathematics education for their young students.

In addition to the highly successful Math Teacher Circles, Dr Ritter is preparing a Teacher Technology Boot Camp to be held at Cochise College in the upcoming summer. The Boot Camp will help new teachers get more comfortable with leveraging technology to provide more engaging student learning experiences in mathematics classrooms.

Other STEM enrichment workshops provided by partners of the program have offered a wide variety of additional learning opportunities to the Noyce Border Scholars. Project Wild, a partnership with the Department of Fish and Game, teaches students about wildlife conservation and environmental responsibility. Further, the UA Center for the Retention and Recruitment of Math Teachers offered twelve sessions to support mathematical pedagogy and Rethinking Schools' Bill Bigelow ran a workshop on Bringing Environmental Justice into the Classroom, offering scholars techniques to bring current environmental events into their curriculum.

The University of Arizona MEd Program supports a robust Professional Learning Community (PLC), built around the specific needs of regional teachers and open to all NBS participants. A minimum of two professional development sessions a month provide the Scholars with opportunities to learn, network and build collegiality. Content provides instruction on practical topics such as classroom management and lesson planning.

Other content is contextual to teaching in borderland schools and includes sessions on Resilience in the Classroom, Addressing Recent Gun Violence in Schools and Growth Mindset in the Classroom. In addition to sessions on Deferred Action for Childhood Arrivals (DACA) and on Understanding Immigration Policy and Supporting DACA Students. There are also sessions on Bringing Environmental Justice into the Classroom, Birding through Citizen Science and The Intersectionality of Border Pedagogies in Secondary Education.

Retaining the Next Generation

Dr Kralovec recognises that one of the biggest problems in secondary education is the retention of qualified teachers, particularly in STEM subjects. The education background that goes with obtaining STEM certifications can be arduous, and many potential STEM educators choose to pursue more lucrative careers rather than going into secondary education that can be a challenging career with low financial return.

This is particularly true in Arizona, where teacher pay ranks 49th in the nation and investment in public schools is poor. In addition to professional development support, the Noyce Border Scholars receive two years of retention support with continued coaching and peer support from university faculty. This is along with participation in the monthly TES sessions that help build a STEM educator support community, while simultaneously providing additional pedagogical content knowledge. Thanks to ongoing support, UAS MEd students remain in teaching positions longer than the national average, providing ongoing high-quality education to borderlands students.

The University of Arizona South's Noyce Border Scholars program is rethinking how we train and retain STEM educators in schools. The success of the program highlights how beneficial a multifaceted approach that incorporates training, mentorship, and community, can be to new teachers from all walks of life. As the program continues into the future, Dr Kralovec hopes to expand upon current successes and train even more outstanding STEM teachers, who can support the education of the next generation of scientists for the Arizona borderlands. According to Kralovec, 'This work will involve using a "Grow your Own" model of teacher preparation, where we recruit students in border high schools and support those students through their college years, working closely with them on the path to teacher certification. Students in border communities have unique challenges and schools on the border are federally designated high-needs school where some students cross the border each day to attend school. We have found that the best teachers we have prepared often come from the communities where they now teach.'

Meet the researcher

Dr Etta Kralovec, EdD
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Etta Kralovec obtained her Doctor of Education in philosophy from Columbia University, with a dissertation that explored the philosophy of John Dewey in the context of ecological thinking. She went on to serve in numerous educational leadership positions in prestigious institutions across the United States, including the College of the Atlantic and Pepperdine University, also receiving a Fulbright Fellowship to join the faculty of Africa University, Zimbabwe for a year. She joined the faculty of the University of Arizona, South (UA South), in 2006, and is currently Professor of teacher education and Co-PI on a National Science Foundation grant. Dr Kralovec has received many awards for her contributions to education including the Distinguished Outreach Faculty Award from the University of Arizona in 2015 and the Distinguished Alumni Award from Teachers College, Columbia University in 2018 and from Lewis and Clark College in 2002. In 2017, she received an honorary MPhil degree in Human Ecology from College of the Atlantic. She has published widely in both the popular press and in academic journals including many books on rethinking educational practices for the 21st century, including, *The End of Homework, Schools that Do Too Much*, and *Identity in Metamorphosis*. Under her direction, the MEd program in secondary education at UA South has developed a contextualised approach to preparing teachers for border schools, preparing critically conscious teachers for the complex border educational environment. It has received over three million dollars in federal funds to prepare science, technology, engineering and math (STEM) teachers for schools in Arizona border communities and the program was awarded the Peter Likins Inclusive Excellence Award from the University of Arizona in 2015.

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THE UNIVERSITY OF ARIZONA South

CHALLENGING STUDENTS TO REACH FURTHER IN SCIENTIFIC EDUCATION

Associate Professor of Biology at Lane College, **Dr Melanie Van Stry** is undertaking educational and scientific research to support students in achieving their maximum academic potential. Her goals are to increase student retention and to improve learning and scientific skills in biology and chemistry degree courses.

Lane College, Tennessee

Lane College was founded over a hundred years ago in 1882 shortly after the US civil war had ended. In that time the college has seen significant expansion and development. Subsequently, there has been a dramatic increase in student numbers, with around 1,500 students enrolling each year. The college awards the internationally recognised bachelor's degree, the baccalaureate, to students successfully completing its educational programmes in science or the arts. The college recognises that in a constantly-changing world it is important to educate the whole student, so that students can contribute more fully to society.

Student enrolment for Lane College is highest from the African American community, with many students being the first from their family to enter higher education. High schools that supply students to Lane College tend to be underserved. This means they do not receive equal funding and the student intake is generally from low income families. Over 90% of students attending Lane College receive government funding in the form of a financial grant to enable them to fund their education.

One of the major problems facing Lane College is the poor rate of retaining students over an extended period so that they can graduate with a bachelor's degree. There are approximately 400 students enrolled in scientific subjects, mainly biology and chemistry, computer science and mathematics (STEM subjects). However, the retention rate for biology and chemistry is less than 50% after the first year, with another significant reduction in student numbers after their sophomore (2nd) year at college. The award of degrees at Lane College over recent years has ranged from 26–34%.

The 'Targeted Infusion' Project

Dr Melanie Van Stry has been awarded significant funding to tackle this problem of low attainment and low retention rates through her, 'Targeted Infusion Project – The Infusion of Research and Peer-Led Team Learning to Enhance Student Engagement in Foundational Courses at Lane College.' She says that, 'the overall goal of this project is to improve retention through student-focused approaches within foundation courses of general biology and chemistry.' Dr Van Stry and her team are taking an innovative approach by using the latest educational technologies, peer support and increased student participation to tackle these problems.

The project has two main objectives. The aims are to adopt and implement peer tutoring and to increase retention and attainment. To address this first objective, students take part in team-based learning. The intention of this is to improve the student's ability to hold onto the information gathered, to develop higher-order thinking skills and improve performance throughout the course. In addition to this, students will develop skills in reading scientific literature, writing, and problem solving.

This is a distinctly different approach to that traditionally used at Lane College where students are taught in a lecture-based environment and then assessed through

traditional exams and coursework. The focus of this project is to improve student learning of core scientific concepts at the foundational stage, which will lead to increased success at the higher levels of the course.

Another key aim of Dr Van Stry's work is for students to develop the core skills necessary for a career in science through research-based training. There is evidence that minority students who carry out research projects at an undergraduate level are more likely to enter work within that field.

‘Our undergraduate laboratory courses will be transformed from the traditional “cookbook” exercises, where the research result is already established, to a real-world research project where students will make novel discoveries.’

In addition, there are many skills that can potentially be acquired during a research project. These include understanding of the scientific process, quantitative reasoning (the application of basic mathematics to the analysis and interpretation of real-world data), communication and collaboration with other team members and a fundamental understanding of the multi-disciplinary nature of science.

The overall evaluation of the project will be carried out by an independent research group who will look at a range of objective and subjective measures that will be compared to baseline data obtained before the research began.

The success of the project will be determined by evidence of increased numbers of students undertaking biology and chemistry, an improvement in progression rates from 1st to 2nd year and increased degree completion rates at the end of the course. The project is also aiming to increase the numbers of students taking part in research projects at undergraduate level, in addition to an increase in the numbers of students progressing to graduate school.

Subjective measures of the project outcomes will be assessed on an annual basis using both staff and student interviews along with focus groups involving stakeholders.

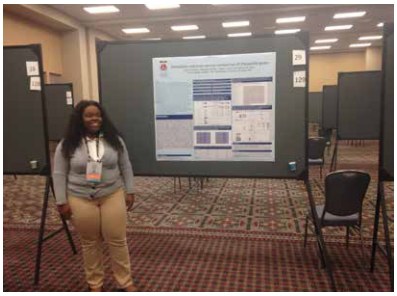
‘The Flipped Classroom’

A traditional learning environment requires students to attend class on a regular basis to receive instruction from their teacher on a topic. They are then given homework to do in their own time where they must analyse and evaluate the knowledge they have gained, usually without structure or guidance. This work may then be assessed and given back to the students with feedback from the teacher.

Dr Van Stry is introducing and testing new ways of learning by giving her students more responsibility for their own learning, increasing the amount of practical work they carry out and building core skills in fundamental scientific concepts rather than just learning individual facts. Dr Van Stry is applying a new concept in teaching called the ‘flipped classroom’ to achieve this.

The flipped classroom delivers educational material online through the internet, through ‘E-Learning’. Educational material is multimedia based, including videos, blogs, articles, interactive animations and quizzes for self-assessment.

One of the main advantages of E-Learning is that educational material can be accessed at any time and from any place. Students can work at their own pace and stop and start



their own lessons, picking up where they left off during a previous session. In this new way of learning, students spend time prior to their scheduled class accessing educational materials online, allowing them to gain a breadth of knowledge and understanding before attending class.

Once in the classroom, the students then deepen their understanding through discussion and problem-solving activities led by their teacher. The students do their ‘homework’ during class time under the guidance of their teacher and tutors.

There are several other advantages to using the flipped classroom concept. The students may replay parts or all the learning material as many times as they like, something not possible in the traditional lecture and the tutors, both teachers and peers, are present when the student is applying their knowledge to problem solving. Current research data indicates that the flipped classroom

generates improved student achievement with better attendance rates and grades. Dr Van Stry says that, 'we are changing the mode of instruction from the traditional lecture to active learning.'

One further important aspect of Dr Van Stry's work is the identification of 'peer tutors and mentors'. These are students with a grade point average (GPA) score of greater than 3.0, meaning they average at least 80% in biology or chemistry. Interested students apply for these positions and are given training in teamwork, leadership, ethics and classroom management.

These students will receive regular guidance from academic staff throughout the research project. Part of the role of the peer tutors will be to support and guide other students in their learning both online and in the classroom, helping to support the learning of their fellow students while developing their own leadership skills.

Student Research

An essential part of this project is the engagement of students in real-world research. Normally, at undergraduate level, students often work on data that has already been collected and the research question supplied to them. However, students taking part in a real-world project with unknown outcomes enables them to define a research question, design an appropriate methodology, collect data, interpret results and write up their findings.

Dr Van Stry describes how, 'we are incorporating instruction into the process of science by engaging the students in course-based undergraduate research experiences in our laboratory courses.' One such proposed biology research project involves isolation and characterisation of antibiotic resistant bacteria.

The purpose of this project is to identify antibiotic resistant bacteria in soil samples and determine how that resistance may have developed by extracting bacteria from the soil and growing them in a laboratory environment in the presence and absence of antibiotics.

The students will then be able to use DNA sequencing techniques to identify, at a molecular level, the bacteria they have isolated. Following this, an enzyme assay can be carried out that leads to the identification of the enzyme that confers the antibiotic resistance of the bacteria. Dr Van Stry has planned this research into 12 individual stages that can be completed in one academic term.

For the chemistry course, the research will introduce the students to technology such as chromatography and spectrophotometry. Chromatography is used to separate out individual compounds from a complex mixture – usually in gas or liquid form. In a real experiment, the students will use chromatography to separate out alcohol from a range of household products to determine its alcohol content. They will then use this technique to determine the caffeine level in coffee, tea and soda.

Spectrophotometry is used to determine the amount of a chemical within a sample solution. It does this by passing a beam of light through the solution and measuring how much of the light is absorbed. This measurement is made at a range of wavelengths that may include visible, infra-red or ultra-violet light. Some chemicals absorb different wavelengths of light and spectrophotometry, allows them to be identified.

The students will use this technique to determine the amount of added food colouring within products from their own homes. Dr Van Stry hopes that, 'our undergraduate laboratory courses will be transformed from the traditional "cookbook" exercises, where the research result is already established, to a real-world research project where students will make novel discoveries.'

The Future of Learning at Lane College

The implementation student-led learning and the use of undergraduate research to improve retention and attainment within biology and chemistry will bring about significant changes for Lane College. Depending on the overall success of this project in biology and chemistry, it would be appropriate to expand the methods to other areas of science that are currently under-represented.

For example, mathematics, physics, computer science and other STEM subjects could benefit from novel methods of engaging, currently underrepresented and underserved young people in education.

Encouraging student engagement in scientific research is key to achieving this. Dr Van Stry describes how, 'to help achieve our long-term goal, we will need to provide research opportunities for students throughout their matriculation at Lane College. We are working to create partnerships with larger, research intensive institutions to allow more of our students to gain exposure to research.'

She is also hoping, in a project recently funded by the American Society for Cell Biology Minority Affairs Committee Linkage Fellows grant, to inspire the next generation of young chemists and biologists at elementary school in an after-school Science Club, where students will be introduced to their first microscope and the single celled organisms of the Lane College pond.

There is huge potential for these creative and innovative methods of supporting young people to inspire the desire and confidence to succeed in education. Dr Van Stry hopes that this success will then translate into rewarding scientific careers.

Meet the researcher

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Dr Van Stry is an Associate Professor of Biology at Lane College, Jackson, Tennessee. She earned her Bachelor of Science in Biochemistry from Boston College in 2000 and her PhD in Biochemistry from Boston University School of Medicine in 2005. She completed her postdoctoral fellowship at St. Jude Children's Research Hospital in the Department of Immunology where she studied T cell development, the genetics of atopic disease and immunity to infections, including *Listeria* and influenza. Dr Van Stry's research interests are in genomics and environmental microbiology. She is a member of the American Society for Biochemistry and Molecular Biology and the American Society for Cell Biology. She has extensive teaching experience in general biology, cell physiology, and biochemistry. She is committed to improving undergraduate education for minority students through the implementation of innovative active learning strategies and undergraduate research.

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INVESTIGATING DISPARITIES IN HIGHER EDUCATION ENVIRONMENTS

Increasing diversity among STEM students is extremely important when it comes to training the workforce of the future. **Professor Rodolfo Mendoza-Denton,** a professor and social psychologist at the University of California, Berkeley, has been carrying out extensive research into diversity within higher educational settings. His recent studies have focused on comparing the academic opportunities offered to students from different socioeconomic and racial backgrounds, and exploring the factors that might encourage underrepresented students to feel that they can succeed in historically White universities.

Increasing Diversity in STEM-Related Fields

Providing equal opportunities for students from underrepresented minorities is a crucial step towards ensuring that the workforce of the future is rich in diversity and culturally varied. This is particularly true for Science, Technology, Engineering and Maths (STEM) – fields that are central to our economies and require highly specialised skills that can only be attained after several years of intense academic studies.

In recent years, universities have been trying to ensure equal access to higher education for students from minority backgrounds – a goal that is particularly important for institutions that have historically denied access to individuals based on characteristics such as race, gender, or social class. Research assessing the opportunities that are currently being offered to underrepresented students within higher education environments is therefore of crucial importance, as are studies investigating factors that might improve these students' wellbeing and sense of belonging when attending historically White universities.

Findings collected during such studies can inform universities and educational institutions, suggesting areas in which they should improve, as well as ways in which they could foster greater diversity within STEM fields or help underrepresented students feel satisfied within their academic setting. Professor Rodolfo Mendoza-Denton has dedicated much of his career to researching diversity within educational institutions, on a quest towards a future in which underrepresented students are given equal opportunities when trying to consolidate their future career.

His laboratory explores a number of different aspects related to diversity, ranging from investigating the actual opportunities that are being offered to underrepresented minorities to probing possible factors that could improve their sense of belonging in historically White academic institutions.

The Impact of Friendships on Students' Institutional Belonging

Studies carried out by Professor Mendoza-Denton and his team have explored factors that affect whether minority students feel like they belong in a university from which they have been historically excluded. One area of investigation has been 'race-based rejection sensitivity', the tendency to anxiously expect, readily perceive, and intensely react to race-based rejection and the role of cross-group friendships in fostering a sense of belonging within a predominantly White academic environment.

In an initial study that spanned over the course of three academic years, Professor Mendoza-Denton's team asked two cohorts of African American college students to periodically answer a series of questionnaires

related to the friendships they had formed in university, their race-based rejection sensitivity, and their general sense of belonging within the institution they attended. When the study took place, African Americans represented less than 10% and Whites more than 50% of the student body at the university.

The team found that minority students' high scores in race-based rejection sensitivity were associated with a lower satisfaction and sense of belonging when attending an historically White university. Friendships with students from the White majority group also appeared to influence students' satisfaction with the university and sense of belonging, in particular for minority students who scored higher on the RS-Race questionnaire, who generally appeared more anxious about racial discrimination.

Guided by their prior studies that found that participating in events related to one's cultural or racial identity could also help students feel a greater sense of belonging at the

university they attended, Professor Mendoza-Denton and his team carried out a second study assessing the role that cross-group friendships could play on perceptions of the university, which involved a group of Latino and White students.

The students were randomly assigned to either a cross-group friendship induction or same-group friendship induction, interventions that prompted them to make friends and achieve interpersonal closeness either with someone from their same cultural group or a different one. The students were also asked to complete the RS-Race questionnaire prior to the intervention and a further questionnaire at the end assessing their satisfaction with the university.

Professor Mendoza-Denton and his team found that students who took part in the cross-group friendship induction displayed overall higher satisfaction with the university, even those who had scored higher on the questionnaire assessing race-based rejection sensitivity.

Overall, Professor Mendoza-Denton's research highlights the importance for students to establish both friendships within the same cultural group and from different ones, as both appear to be linked to higher satisfaction within predominantly White academic institutions.

Working for Equal Opportunities

In another research direction, Professor Mendoza-Denton and his colleagues compared the opportunities that are being offered to underrepresented minority and female students with those offered to male students that are part of the White majority group.

The team ran two independent studies on students completing PhDs in STEM-related subjects at UC Berkeley. These studies revealed that underrepresented minority and female students published research at significantly lower rates than White males, which placed them at a considerable disadvantage when competing for postdoctoral positions.

Overall, only 23% of postdoctoral students from minority groups had submitted a paper for publication, compared to 42% of males from White backgrounds and 32% of females. This difference in the percentage of students who had submitted a paper for publication was apparent in all STEM-related doctoral subjects offered at the university – the only exception being Berkeley's College of Chemistry, for which publication rates appeared to be spread more evenly across different ethnicities and gender.

Professor Mendoza-Denton attributed the differences observed in the College of Chemistry to the highly structured nature of the program, which includes early and systematic involvement in research for all students, who are given clear expectations to publish their work. In fact, Berkeley's College of Chemistry requires lab rotations for its students, and the expectations for publication are made clear from the very beginning.

The findings made by Professor Mendoza-Denton and his colleagues are aligned with previous social science research that has found that more structured environments tend to promote successful induction of students from minority groups into STEM academic training. This highlights the need for colleges to restructure their doctoral training programs to ensure that students from minority groups are offered equal opportunities throughout their PhD, placing them at an even position when trying to secure a postdoctoral job.

Further research into the particular factors that might be behind this disparity in research publications could help to devise interventions aimed at dissipating inequalities and encouraging a more diverse workforce in the future.

Exploring Factors that Could Affect Health

Over the course of his career, Professor Mendoza-Denton has also carried out important research exploring the social and psychological factors that might lead to poor health or inflammation in underrepresented minority students.

One study he carried out on a group of Latino students found that those with greater anxious expectations of rejection appeared to have higher levels of the circulating Interleukin 6 (IL-6) – an inflammatory cytokine that has been linked to health vulnerabilities. This effect appeared to be attenuated in students who resided in culturally-based theme dormitories during their first year at university.

In another study involving a group of adults, Professor Mendoza-Denton's laboratory found that implicit social class bias, the automatic positive or negative associations that individuals might make with upper and lower social classes, and subjective social status, how wealthy one believes they are, could also impact on the levels of the inflammatory cytokine IL-6. In other words, individuals who were found to generally attribute negative connotations to lower social classes and those who perceived themselves as having a low social standing, appeared to be more vulnerable to inflammatory processes.

Professor Mendoza-Denton's work also explored the relationship between racial bias and health risks. In particular, his laboratory found that counties where the White population report higher explicit and implicit racial bias have a greater disparity in circulatory-disease risk between White and Black inhabitants, such as pronounced differences in access to healthcare and death rates related to circulatory diseases compared to areas with low explicit and implicit racial bias. This work suggests that racial biases have health outcomes for both majority and minority members.

Heading Towards Greater Diversity in STEM Fields

As technology and science keep developing at an increasingly faster pace, ensuring that the workforce of the future is well-equipped to cover STEM-related positions is of crucial importance. It is also vital to ensure that all individuals, regardless of their ethnicity or gender, are offered equal opportunities and support when pursuing their chosen career path.

Professor Mendoza-Denton has dedicated much of his career to researching important aspects of ethnic and cultural diversity, both inside and outside higher education settings. His team's work has shed light on the disparities that are still present between PhD students who are part of the White majority population and underrepresented minorities at renowned universities. Furthermore, his research has been able to pinpoint the importance of developing friendships from different ethnic backgrounds to heighten success for all students at university.

Over the years, Professor Mendoza-Denton and his colleagues have also collected meaningful evidence unveiling links between racial sensitivity, biases, or perceived social status and health-related risks or inflammation rates.

Ultimately, Professor Mendoza-Denton's research could provide the basis for future initiatives aimed at dissolving inequalities relating to the opportunities offered to students from different ethnic groups or at increasing their wellbeing and sense of belonging at their academic institution. This would eventually encourage greater diversity among STEM-related fields, by ensuring that underrepresented minorities are adequately supported and stimulated in their path towards noteworthy professional accomplishments.

Meet the researcher

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Professor Rodolfo Mendoza-Denton completed a BA in Psychology at Yale University, followed by an MA and PhD at Columbia University in New York. He then worked as a postdoctoral researcher for three years, before taking his current position as a Professor of Psychology at the University of California, where he is also the Associate Executive Dean for Diversity and Inclusion. Professor Mendoza has carried out extensive research related to cultural identity, diversity, and the integration of minority students within academic environments. He has been invited to give many talks about inclusion and diversity at conferences and public events. His work has received numerous grants, the latest of which was assigned by the National Science Foundation for a project aimed at increasing the success or underrepresented postdoctoral fellows specialising in Mathematics, Engineering, and Computer Sciences. Professor Mendoza has also received a number of awards, the latest being the Distinguished Service to SPSSI Award (2017) from the Society for the Psychological Study of Social Issues (SPSSI) and the Mitigating Bias Research Innovation Prize (2017), awarded by the Kapor Center for Social Impact.

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Berkeley
UNIVERSITY OF CALIFORNIA

BUILDING STEM OPPORTUNITIES FOR STUDENTS WHO LEARN DIFFERENTLY

As one of only two post-secondary institutions in the United States exclusively serving students with learning disabilities, attention deficit disorders and those on the autism spectrum, Landmark College has a reputation for excellence in education. **Professors Michelle Bower** and **Abigail Littlefield** of Landmark College are creating educational, mentorship and employment opportunities for students who learn differently and who are enrolled to study science, technology, and mathematics.

Access to Innovative Education

When Dr Michelle Bower, then chair of the Mathematics and Computer Science Department at Landmark College, noticed that many academically gifted science, technology, engineering and mathematics (STEM) students struggle financially and with employment after graduation, she decided to do something about it. Drawing on the success of a previously awarded Johnson Scholarship Foundation grant titled *Access to Innovative Education* – which provided support to any academically talented student who was in financial need at the college – Professor Bower and her colleague, Professor Abigail Littlefield of the Department of Natural Science at Landmark College, wrote a grant requesting further funding to support the college's full-time, academically gifted STEM students.

The name of the proposed program was '*Access to Innovative Education – STEM Opportunities for Students with Learning Disabilities (AIE-STEM)*.' The grant had three goals: to provide financial support to low-income, academically talented students in the Computer Science and Life Sciences programs; to offer them mentorship opportunities within the college; and to provide access to internships and employment opportunities after graduation.

'We designed the program for college learners who have dyslexia, Attention Deficit Disorders, Autistic Spectrum Disorder, and/or other profiles,' said Professor Bower of the project. In August of 2016 the team was successful, and the NSF awarded the $650,000 grant to the College. In September of that year, selected STEM students began receiving financial aid.

Vermont Senator Bernie Sanders also weighed in on news of the grant. 'At a time when the skyrocketing cost of college has pushed higher education out of reach for many Vermonters, I am pleased Landmark College and the National Science Foundation have partnered to create an innovative program to help low-income students with learning disabilities pursue science and technology degrees,' said Senator Sanders. 'We need more efforts like these to make college more affordable to more people.'

In the first year of the *AIE-STEM* project in September of 2016, seven students were awarded scholarships. Over the five-year grant period, five to thirteen scholarships will be awarded per year, for a total of 45 awards, with most of those at the maximum $10,000 level.

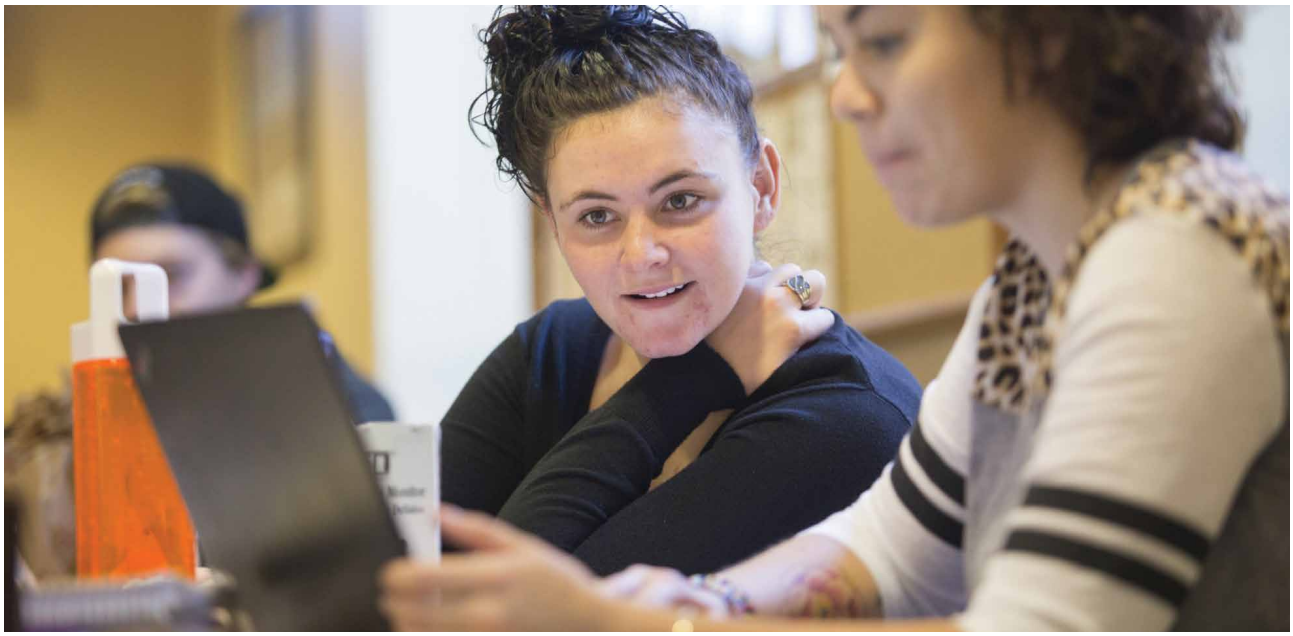
Professor Bower oversees all components of the grant and supports other faculty in their teaching, research and mentoring activities, including ongoing professional development of faculty within the Computer Science Department. Professor Littlefield co-directs the grant with Dr Bower and supports

faculty in the Life Sciences department. Both professors support the recruitment, selection and retention of the *AIE-STEM* scholars.

Landmark College, A Pioneering Institution

Located in Putney, Vermont, Landmark College opened in 1985, trailblazing a path for students who learn differently so they can pursue a quality post-secondary education tailored to their unique needs. As a non-profit educational institution, the college was the first to pioneer college-level studies for students with dyslexia. Today, the College offers a number of associate

‘We are excited to work with students for whom a program like ours may have been out of reach financially. There’s talent out there, and we look forward to mentoring more students who will go on to make contributions to STEM.’



and baccalaureate degree programs in areas including liberal studies, business, studio art, computer science, life sciences, and psychology. All students enrolled at Landmark College have a diagnosed learning disability, attention deficit disorder, and/or autism spectrum disorder.

Landmark College has offered two-year associate degree programs in life sciences and computer science (AS) since 2012 and recently launched a four-year baccalaureate program in computer science (BS). The science program has expanded over the last few years and most recently, a new building was constructed to house both the life sciences and computer science faculty. The building, named the Nicole Goodner MacFarlane Science, Technology & Innovation Center, opened its doors in August 2015 and also houses the Landmark College Institute for Research and Training (LCIRT).

To be eligible for the *AIE-STEM* award, students must be enrolled full-time in an AS or BS degree and have good academic standing (GPA of 2.5 or higher). Recipients must be a US citizen, national, refugee, or permanent resident, and also demonstrated financial needs as outlined by the US federal government.

As an access grant, program leaders seek to support a diversified cohort of students pursuing the STEM fields, and thus actively seek to bestow awards to first-generation and female students, and students of colour. Recipients must adhere to all program requirements including regular meetings with a faculty mentor and participation in at least one internship. Bachelor of Science students must also participate in research.

Life Sciences students who qualify for the grant program engage in field work, data collection and experiment design. Students in Landmark College’s Computer Science program are involved in data mining, computer modelling, robotics, and design of hardware and software. All students are expected to contribute to weekly laboratory meetings, participate in training opportunities, and present their research findings.

Creating Mentorship Opportunities

Current research suggests a much smaller proportion of students with disabilities complete a four-year undergraduate degree within six years, compared to that within the general population. One primary goal of the *AIE-STEM* grant program is to increase the graduation rates of students enrolled in STEM programs at Landmark by supporting low-income, academically talented students with learning disabilities in both the Computer Science and Life Sciences programs, from enrolment to graduation.

It is hoped that graduation rates for *AIE-STEM* scholars will increase to between 39–58%, exceeding the institution’s graduation rate of 39%. Landmark only began offering four-year degrees in 2012, and prior to that was a transitional two-year college – as a result, its graduation rate appears lower than many other US institutions. In their first-year report, Professor Bower notes that the retention rate for the year of students who had received support was 80%, exceeding the original goals of the program.

Another goal of the *AIE-STEM* program is to create a culture of mentorship within the Computer Science and Life Sciences

departments. The best procedures for mentoring students with learning disabilities are not yet well understood and therefore the role of faculty mentoring of students with a learning disability is a prime area of research for the *AIE-STEM* project. The mentorship program includes advice sessions with students on a regular basis, an approach that emphasises students' strengths, with an emphasis on growth, non-directive questioning, facilitated inquiry, and on preparing for the future. All *AIE-STEM* scholars are assigned a faculty mentor within their discipline.

In addition to online and on-site training for its faculty and staff, as part of the grant program the College offers professional development for *AIE-STEM* for faculty mentors. Faculty mentors are deeply invested in helping their mentees engage in the professional experiences that support enhanced learning in their fields. Faculty mentors meet regularly with their students, and also attend trainings and workshops focused on best practices for student mentoring.

Strengthening Partnerships with Industry

Research has suggested that a small proportion of the US workforce is comprised of individuals with disabilities and only a fraction of those are employed in science and engineering professions. Rates of employment for individuals with disabilities working in science and engineering professions continues to be low and the *AIE-STEM* program is attempting to directly address this by building partnerships with private industry and other outside organisations, working to increase the number of internships available to these students.

All recipients of awards complete at least one internship during their course of study. To help scholars reach these goals, the college set up special partnerships with several outside institutions including the Vermont Genetics Network, the Vermont Established Program to Stimulate Competitive Research (EPSCoR), and the Rich Earth Institute and software company Lexalytics Inc.

In addition, Landmark College also formalised a partnership with the toy company Hasbro, Inc. and with Bosco Genetics for summer internship opportunities. Other internship positions included jobs in internet technology, biotechnology lab assistant positions and computing. In 2017 two new partnerships were forged with Inventive

Labs, a company that helps students who learn differently start a business or discover a career, and Broad Futures, an organisation that provides mentorship and work experience for students with a learning disability.

The Future of STEM Education at Landmark

In total, seven unique students were supported by the *AIE-STEM* grant program during the 2016-2017 academic year. During the next five years, a total of 45 full scholarships will be awarded and these will include mentoring and employment opportunities through the grant.

During the 2016-2017 academic year 75% of students who received awards reported a positive research experience in interviews, as well as an overall appreciation of their monthly meetings with faculty members. In addition, faculty who were interviewed thought that mentorship helped undergraduate students and improved their research and scholarship experiences. There was also strong agreement among faculty that mentoring strengthened the department as a whole.

Only a year into the program, it is too soon to know what the exact outcomes for the program will be, but with promising results so far, Professors Bower and Littlefield are looking forward to the coming years. 'We are excited to work with students for whom a program like ours may have been out of reach financially,' said Dr Bower. 'There's talent out there, and we look forward to mentoring more students who will go on to make contributions to STEM.'

Meet the researchers

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Professor Michelle Bower joined Landmark College in 2008 after a career as a high school mathematics and physics instructor and as a junior (intern) mathematician for the US Navy. She completed her PhD in Mathematics Education at Illinois State University, and an MA in Mathematics at Ball State University. Dr Bower has been the chairperson of the mathematics and computer science department at Landmark College for eight years. Her research interests include the field of mathematics anxiety and language genres in mathematics education and technology.

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Professor Abigail Littlefield obtained her BA in Human Ecology at the College of the Atlantic, Maine, her MS in Environmental Studies at Antioch New England Graduate School and her Master of Arts in Teaching (MAT) at The Graduate Center at Marlboro College, Vermont. She has taught science to students with language-based learning disabilities, attention deficit hyperactivity disorder and those on the autism spectrum for over 25 years. She has presented nationally on teaching science to students who learn differently and the use of technology in teaching. Her current research focus is looking at the effects of animal assisted therapy and learning outcomes for students who learn differently.

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ADDRESSING INEQUALITY IN EDUCATION

The underrepresentation of women and minority groups in science, technology, engineering, and mathematics (STEM) related fields of employment and study is a widespread and serious issue in academia. **Dr Suzanna Rose** of Florida International University (FIU) is breaking down the barriers that women and minorities face in taking up faculty positions within higher education institutions. Her mission is to achieve, sustain and advocate for faculty diversity at FIU.

The Barriers to Equity and Diversity

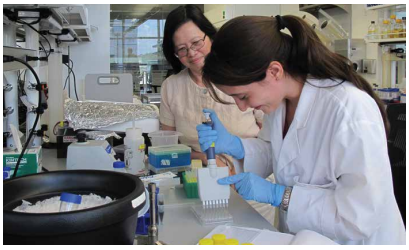
Addressing the underrepresentation of women and minority groups in science, technology, engineering, and mathematics (STEM) is high on the global agenda. STEM related fields of study and employment have long been dominated by specific sub-sections of the global population. In the United States, the representation of women, people with disabilities, and members of certain racial and ethnic groups in STEM, as a percentage of the total, does not begin to match the representation of these groups in the general population. Furthermore, instances of gender and racial harassment, discrimination, and inequity in STEM-related fields of employment and study continue to come to light.

Indeed, there are many obstacles to women and minority groups reaching out for greater opportunity and advancement, especially in higher education institutions, and no less so than in higher faculty positions. It is vital that this be addressed by way of systemic change and improved practice, policy, and education. Dr Suzanna Rose and her colleagues at Florida International University's Office to Advance Women, Equity & Diversity (AWED), in collaboration with other researchers and stakeholders, are very much committed to this cause.

Dr Rose says that: 'It's simple. A diversity of perspectives enriches the sciences, mathematics and engineering, and it makes these professionals more responsive to global needs. At a time when engineering and science are increasingly important to our economy and competitiveness, we need a diverse pool of science and engineering faculty – including women and minorities – to fuel our future.'

Similarly, Dr Yesim Darici, Co-Principal Investigator (Co-PI), Professor of Physics, Director of the Center for Women's and Gender Studies and Assistant Provost for STEM, noted: 'In this day and age, we need to ensure women's voices are heard. There are many obstacles women in academia and industry face throughout their careers and now is the time for everybody to be aware of them. As such, it's important to educate both international faculty and US faculty on issues of diversity and equity.'

Their approach to tackling the issue is multi-faceted. The team describes how, 'AWED develops and manages a wide range of programs to promote faculty equity, diversity, and inclusion, including workshops and training to improve faculty hiring and promotion processes, faculty mentoring, and interdisciplinary networking.' Other activities include strategic planning for salary equity, policy analysis and development, and other initiatives that support faculty diversity. Of particular note is their program known as 'FIU ADVANCE.' FIU ADVANCE aims to increase, retain, and promote more women and underrepresented minorities throughout their institution, especially in higher faculty positions, and has initiated two new directions for achieving these goals. First, it addresses the gender, cultural, and ethnic biases implicit in the field, and second, it focuses on promoting behavioural change as well as paradigm shifts in attitude through its Bystander Leadership Program.



The National Institutes of Health awarded Biomolecular Sciences Institute Director and Chemistry Professor, Yuk-Ching Tse-Dinh (left) and colleagues, nearly $2 million to study how targeting bacterial DNA can be used to kill antibiotic-resistant superbugs.

Sheryl Weir-Latty and Cynthia LeRouge, College of Business, enjoying the Super Networking exercise at the 8th Annual FIU Women Faculty Leadership Institute.

Why FIU ADVANCE Was Needed

Dr Rose and her colleagues established the FIU ADVANCE project to address the changes that were needed at FIU. Given the university's excellent record of incorporating diversity, however, the notion that FIU needed

‘It’s simple. A diversity of perspectives enriches the sciences, mathematics and engineering, and it makes these professionals more responsive to global needs. At a time when engineering and science are increasingly important to our economy and competitiveness, we need a diverse pool of science and engineering faculty – including women and minorities – to fuel our future.’

FIU physicist and Director of the Center for Imaging Sciences, Angie Laird, leading a team of researchers embarking on a new phase of the National Science Foundation’s BRAIN Initiative, titled the Automated Text Harvesting and Exploration of Neuroimaging Annotations (ATHENA) Resource.

to improve its practices may have at first seemed unnecessary. Indeed, in 2015, FIU had 54,000 students, of which 61 percent were Hispanic and 20 percent were from other underrepresented groups. FIU was number one in the nation in awarding bachelor’s and master’s degrees to Hispanic students and second in terms of granting STEM degrees. Furthermore, of the 10,170 undergraduates in STEM departments in Fall 2015, 42 percent were women and 32 percent were women of colour. So why was FIU ADVANCE needed?

The team had identified a problem. The diversity in the student body was not reflected at the faculty level. And of course, this could have a long-term negative impact on student success, their aspirations for faculty positions, and the attitudes of the community. Dr Rose and her colleagues have highlighted some startling statistics in relation to this issue. For example, after an initial five-year effort from 2011 to 2016 to increase the number of women in tenure-line, research faculty positions in STEM, the percentage of women had increased from 12% to 18% – well short of the national average of 31% – with only four of the 255 combined STEM faculty members being women of colour. This was a positive but exceedingly slow change.

What was even more notable was the attitudes that had contributed to this poor representation of women and minority groups in faculty positions. Women reported feeling less respected by the faculty in their departments, that they were taken less seriously in departmental meetings, and were more dissatisfied with how tenure and promotion was managed in their department. This situation was contributed to by low morale and ultimately the low number of women and minority groups in higher faculty positions.

Furthermore, past research conducted by Dr Rose, Dr Darici, and their colleagues about STEM faculty and intersectionality and the interconnections of gender, race, class, and cultural identity had suggested unique barriers to recruiting minority and underrepresented women. FIU is a multicultural institution, but that means faculty members from around the world bring with them culturally-based gender stereotypes about women from their own culture and different gender-by-cultural stereotypes about women from other cultures. As a result, Dr Rose and her team felt that it was time to intervene and be a force for change and so FIU ADVANCE was initiated.

The Central Goals of FIU ADVANCE

FIU ADVANCE was preceded by a National Science Foundation (NSF) program and funding initiative. The NSF ADVANCE program was established to, ‘increase the representation and advancement of women in academic science and engineering careers, thereby contributing to the development of a more diverse science and engineering workforce.’ Their approach focuses on the aspects of an institution’s structure, processes, and culture that may be contributing to an inherent bias towards women and minority groups. The NSF has invested over $270M to support ADVANCE projects at more than 100 institutions of higher education and STEM-related not-for-profit organisations in 41 states, the District of Columbia, and Puerto Rico, including at FIU.

FIU’s ADVANCE program focuses on four central objectives. Firstly, to attract, recruit, retain, and promote more women STEM faculty, particularly underrepresented minority women, to better reflect the demographics of the FIU student body. Secondly, to educate faculty about gender-by-ethnic biases and microclimates that affect the advancement of women. Thirdly, to move faculty from insight to action to promote gender equity by developing and implementing an evidence-based intervention program and a university-wide diversity, inclusion, and excellence plan. Finally, they aim to develop the ADVANCE Florida Network, a joint steering committee and seminar series for women STEM faculty and postdoctoral fellows comprised of the Florida metropolitan research universities of FIU, University of Central Florida, and University of South Florida.

A Thorough and Systematic Approach

The theoretical basis for FIU ADVANCE is being established by ongoing and relevant social studies. These studies began in year one of the program, in which Dr Rose and

FIU women faculty with Kathrin Zippel, keynote speaker, sociologist, Northeastern University, and author of Global Women in Science (2017).

her team explored how a multi-ethnic cultural climate within FIU STEM departments could affect the advancement of women. In addition, in research that spans from the second to the fifth year of the program, the team will examine the longitudinal effectiveness of their Bystander Leadership Program in improving diversity related knowledge, beliefs, attitudes, and behaviours among professors. This research will be a source of feedback and will continue to inform the implementation and improvement of FIU ADVANCE.

The project's central goals are to be achieved by several detailed programs and initiatives. These initiatives focus on changes to recruitment and advancement practices, providing high quality support and mentoring, reviewing current departmental policies and procedures, networking with other experts and organisations, communicating relevant information and successes to the public, and carrying out effective and meaningful evaluation and reflection.

Some of FIU ADVANCE's Programs and Strategies

The Bystander Leadership Program is one facet of FIU ADVANCE. It aims to address discrimination by not only educating and raising awareness about issues such as bias, power and privilege, intersectionality, and oppression, but by providing a framework for action. The program does not simply dispel information to attendees but uses case scenarios and interactive theatre to actively engage faculty in skills training, so that they can practice effective intervention techniques that address instances of bias.

The subsequent program interventions help to create a social system that supports and institutionalises positive change in several key areas – including demonstrating greater appreciation for diversity and a reduction in prejudicial attitudes, greater knowledge of and confidence in using intervention and diversity skills and strategies, and an increase in diversity-affirming behaviours.

Another central initiative of FIU ADVANCE is the creation of diversity and inclusion action plans by all colleges and departments at the university. These plans, currently under development, aim to increase the representation of faculty from historically underrepresented groups and to ensure an equitable and supportive institutional climate for all faculty, students, and staff.

FIU ADVANCE's programs and strategies highlight the project's thorough and systematic approach that is key to its current and projected success. Targeting diversity in recruitment, the STRIDE program purposes to educate faculty on how to create a more diverse pool of candidates when hiring for STEM-related positions and the Women in STEM program aims to recruit more women by way of targeted outreach, recruitment, and support practices. The ADVANCE Florida Network follows on from that to provide mentoring, networking, collaboration, and professional opportunities to tenured and tenure-track STEM women faculty and STEM women postdoctoral fellows among the three urban public research universities in Florida.

FIU ADVANCE Already Making a Difference

Evaluation and measurement of the FIU ADVANCE project's success is systematic, thorough, and formative. Evaluation consists of both internal and external assessment. For example, Dr Mariko Chang – a sociologist who has served as an external evaluator for many ADVANCE grants and on ADVANCE review panels and site visit teams – serves as FIU ADVANCE's external evaluator. Dr Barbara King serves as internal evaluator and provides in-house assessment of the success and efficacy of activities throughout the project.

The project's assessment criteria are aligned with their respective objectives and consist of both quantitative and qualitative parameters. For example, each objective has an associated list of evaluation questions and numerical benchmarks or indicators, as well as further data evaluation procedures such as surveys, interviews, reviews and auxiliary data collection. While in the fifth year of FIU ADVANCE it will be subject to a full review and summative assessment, initial reports and reviews indicate that the project is already having a positive impact.

For example, the STRIDE workshop series has been successfully conducted and, according to a 2017 progress report, has been well received by attendees. 82 percent of participants expressed that the workshops were effective in helping them to understand the benefits of having a diverse faculty, the role of stereotypes in career advancement, and how to find solutions to these issues.

The ADVANCE Florida Network (AFN) initiative has also yielded positive results. In Fall 2016, a steering committee for the initiative was established, including Dr Rose and colleagues, and they developed guidelines for what's known as the 'ADVANCE Florida Network Women in STEM scholars' strategy. This strategy aims to highlight and support the professional work of women in STEM-related faculties by funding their travel to one of the three urban public research universities that comprise the Florida Consortium of Metropolitan Research Universities in order to foster research collaborations and networks.

Twenty-two applicants have been awarded funding since 2016, with participants reporting numerous benefits after having engaged in exchange programs and professional development. For example, during an AFN visit, faculty at the host institution told one participant about the McKnight Junior Faculty Fellowship, which the AFN participant subsequently applied for and received. The award includes a one-year sabbatical and $15,000 to the institution. Similarly, another participant was encouraged during her visit to apply for an NSF CAREER award, which she was recently awarded. The award is for $760,607 over five years.

Clearly, FIU ADVANCE is already having a significant, positive impact. It will only continue to do so as it moves towards completion. There are many barriers to women and minority groups reaching out for faculty positions in higher education institutions and it is vital that this is addressed by way of systemic change and improved practice, policy, and education. FIU ADVANCE is certainly already achieving that – removing the obstacles to advancement for many women and minority groups.

Meet the researcher

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Suzanna Rose, PhD, is founding Associate Provost for the Office to Advance Women, Equity & Diversity and Professor of Psychology and Women's and Gender Studies at Florida International University. Dr Rose is also the lead investigator for FIU's NSF ADVANCE Institutional Transformation grant that is aimed at improving the recruitment, promotion and retention of women and underrepresented minority faculty at FIU. A key research project associated with the grant includes the development of an evidence-based Bystander Leadership Program to reduce gender and race bias in faculty hiring, promotion, and retention. Her previous administrative roles included serving at FIU within the College of Arts, Sciences & Education as Executive Director of the School of Integrated Science and Humanity, Senior Associate Dean for the Sciences, Chair of Psychology, and Director of the Center for Women's and Gender Studies. Prior to that she served as Women's Studies Director and Professor of Psychology at the University of Missouri-St. Louis. Dr Rose has published extensively on issues related to gender, race, and sexual orientation, including professional networks, career development, leadership, friendship, and personal relationships. She has consulted with many universities both nationally and internationally concerning strategies for recruiting and retaining women faculty in science and engineering.

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SEEDS OF CHANGE – PROMOTING STEM CAREERS FOR WOMEN

Gender disparity in Science, Technology, Engineering and Mathematics (STEM) at the highest levels of universities remains prevalent, despite consistent increases in the numbers of female students entering many of these fields as undergraduates. **Professor Margaret Bailey** of the Rochester Institute of Technology, NY, is combating this issue by identifying ways in which female faculty can be supported and retained through the restructuring of organisational structures within universities.

Science thrives on diversity. The pinnacles of human innovation are seldom the work of a single mind, but more often are the combined efforts of multiple researchers and thinkers contributing ideas and insights, that come together into something that changes the world as we know it.

When these thinkers are from diverse backgrounds, they bring novel perspectives and insights to the problem at hand that can benefit the group as a whole. Science offers the solutions to some of the greatest challenges we face today, from climate change, to water shortages, to pollution and energy crises. Our future hinges on the innovations that science will produce, and the most transformative innovations often come from the most diverse groups of minds.

However, science, technology, engineering, mathematics, and the social and behavioural sciences (STEM/SBS) all face a diversity problem. Despite numerous programs to increase the numbers of women and underrepresented minorities in STEM/SBS career pipelines, there is still a large gender gap in the upper levels of academia, largely due to the attrition of female students throughout multiple stages of undergraduate and graduate education.

Even when women make it into faculty positions, they are less likely to stay in one university for the duration of their career, but rather bounce persistently from university to university looking for better opportunities. The problem is perhaps best illustrated in STEM fields in which there is less of a disparity in student ratios. In the field of biology, for example, women typically outnumber men throughout each level of early career progression, from undergraduate to graduate level, where slightly over half of biology doctorates are awarded to women.

However, the ratio begins to change at the faculty level and by the time you reach senior tenured faculty, men outnumber women 2 to 1. What is the source of this gender disparity in the highest levels of academia, if it cannot be simply attributed to less female students entering the career pipeline? More important, what can be done to support the careers of women scientists such that they want to stay in academia?

Dr Margaret Bailey and a team of researchers spanning multiple universities are working together to find solutions that keep women in STEM with the goal, 'to create positive change within our university that will ultimately increase the number of women faculty teaching and conducting research related to STEM, while improving their careers. With continued efforts, some of the seeds planted during this project will flourish and push the university towards a new normal.'

Defining the New Normal

The new normal that Dr Bailey envisions begins with understanding what factors help some groups of people easily climb the career ladder in academia, while other groups languish in the lower levels, struggling to grab the next rung. Her work focuses on

social resource theory, the idea that there are resources within social networks that promote an individual's upward mobility. Individuals who are able to easily utilise these resources experience faster career growth, while those that have to struggle to gain access to them will enjoy less career success.

For example, a man navigating the career ladder of a research university may enjoy the benefits of more networking and mentorship opportunities from other male faculty. An equally capable woman in the same position may have to try much harder to gain access to the same benefits, or even be altogether excluded from them.

‘The project’s goal is to create positive change within our university that will ultimately increase the number of women faculty teaching and conducting research related to STEM, while improving their careers. With continued efforts, some of the seeds planted during this project will flourish and push the university towards a new normal.’

This is particularly true of women of colour and/or women with disabilities, who are even more likely to face subtle discrimination in academic settings. By understanding the factors that influence resource availability to different groups of people, Dr Bailey drives initiatives that remove barriers to academic career satisfaction and advancement for women, particularly for minority and disabled faculty.

Her work in this area began when she spearheaded a study to identify exactly what the barriers were to female academic career advancement at earlier stages in one of STEM’s most critical fields, engineering. Over three years, from 2008 to 2011, Dr Bailey and a team of colleagues at four US universities engaged in, *‘Pathways to Work: Self-Efficacy and Retention of Women in Undergraduate Engineering,’* or *‘the Pathways Project,’* to work to understand the individual and social factors that lead to female student retention in engineering.

Engineering has high dropout rates on the whole, with nearly 40% of first year engineering students changing majors or leaving university all together. Her team hypothesised that self-efficacy, the strength of one’s belief in their own ability to complete a task, could play a large role in how persistent STEM students were in their educational pursuits. This confidence in one’s ability can be highly influenced by social experiences and societal impressions about what types of people can be engineers.

Dr Bailey hoped to identify ways that university programs could build the self-efficacy of engineering students, particularly female and under-represented minority students who are already at a societal disadvantage of self-image in the sciences.

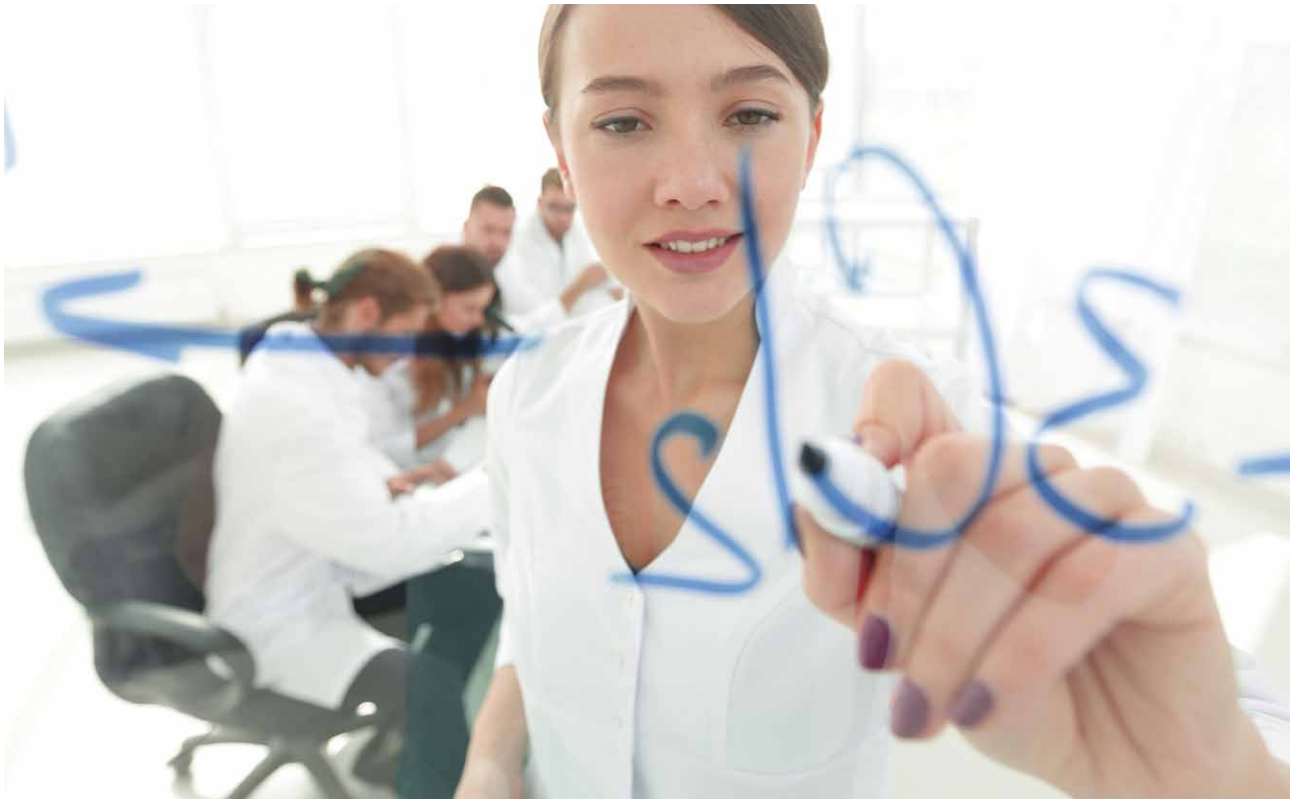
To expand on this concept, Dr Bailey’s team studied the impact of cooperative work experiences, an interesting educational approach in which second through fourth year students, both male and female, participate in cooperative work experience related to their engineering studies. This gave students the opportunity to work as part of a team while applying their newly learned engineering knowledge, with the aim of increasing confidence in their personal engineering abilities through successful utilisation of engineering skillsets in socially supportive environments.

They found that long term retention was enhanced in students that completed cooperative work programs and could be attributed to aspects of social support and increased self-efficacy gained from successful application of learned skills. Further, developing work specific self-efficacy increased the likelihood that a given student would view engineering as a viable career and build habits and behaviours associated with effective working habits in the field.

Transforming Faculty Experiences

The next step in Dr Bailey’s research was to use these findings to create transformational change in higher level academic settings. In 2012 she secured funding from the United States National Science Foundation for their, *‘Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers (ADVANCE),’* program. Her project, *‘Creating Opportunity Networks for Engagement and Collective Transformation – Increasing the Representation and Advancement of Women Faculty,’* aims to plant seeds of change in the Rochester Institute of Technology faculty ecosystem that supports the career development of female faculty, while improving work-life balance and professional experiences for all faculty.

Dr Bailey’s goal for her *ADVANCE* project is to utilise and evaluate a multi-faceted approach to organisational change at the Rochester Institute of Technology and to help women gain better access to social resources, while improving and expanding upon policies that benefit all members of the faculty.



The project team approached this goal from four angles – structural changes, human resources initiatives, political alignment and symbolic changes. Structural changes shift practices and attitudes that affect the advancement of women in faculty positions. To support these initiatives, the *ADVANCE* team engaged in campus-wide faculty climate surveys as well as a salary equity study.

The climate surveys identified many ways in which the dean's office and provost could shift priorities and focuses to better support the faculty community as a whole. The salary equity study found that, indeed, unexplained salary differences existed across gender lines. As a result, the campus experienced increased dialogue around salary structure, and proactive changes to increase salary transparency and resolve inequities across the university.

Salary related data is no longer kept in the dark, but instead is disseminated widely, allowing for more productive conversations during yearly reviews. To implement human resources changes, the program drove more initiatives that support transparency around policies related to work-life balance, such as parental leave policies that make it easier for female faculty to enjoy raising a family and being a professor.

The program also implemented a number of opportunities for professional development driven by human resources policies and procedures, including increased education on unconscious bias in the workplace and active bystander awareness. Politically, the project is working to realign power structures in departments such that female faculty are receiving the same support as their male co-workers.

Through evidence-based development models and educational programs, people in power are engaged in more structured mentoring relationships for junior women faculty. Finally, many symbolic changes are underway to change the university-wide culture around gender. For example, a new *Advocates and Allies* program offers male faculty the opportunity to learn actionable steps they can take to create a more positive work environment for people of all genders and backgrounds.

A Future to Grow Into

As the National Science Foundation *ADVANCE* project continues, Dr Bailey hopes to keep collecting data on what does and does not work to promote equality in academia and see the initiatives she has started grow into meaningful change. She describes how, 'the project has planted several "seeds" to slowly change aspects of the university. There is some evidence that those seeds will continue to grow after the grant is over, and even some evidence of early institutionalisation or rooting. The project's vision is to "reimagine our careers and campus culture" and there are many ways in which we are refining our university to become an even more inclusive campus environment while improving our faculty's abilities to gain more career success. The university is institutionalising many of these seeds and the project's work will continue in order to continue our journey towards the university that we would like to become.'

Meet the researcher

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Dr Margaret Bailey, PhD, PE is the Senior Faculty Associate to the Provost and Principal Investigator for the *ADVANCE* project and Professor of Mechanical Engineering within the Kate Gleason College of Engineering, Rochester Institute of Technology. Dr Bailey is engaged in research related to gender within engineering and science through the National Science Foundation (NSF) Pathways Project, supporting the development of early career female engineers, and the NSF *ADVANCE* Institutional Transformation project, increasing the representation and advancement of women STEM faculty, by removing barriers to career progression. She co-chairs the President's Commission on Women and is also the Founding Executive Director for the nationally recognised women in engineering program WE@RIT.

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INNOVATIVE TEACHING

APPLYING INNOVATION IN TEACHING

It has been noted that fewer than four in ten students who begin college intent on majoring in a STEM subject actually complete a degree in that field. Moreover, according to the US Department of Education, only 16% of American high school seniors are proficient in math and interested in a STEM career. Clearly, there are issues with education quality and college preparedness, as well as retention in STEM related university degrees. As we've seen in our previous section, another pertinent issue is lack of diversity. The relative percentages, or representations of African-American, Latino and Native American students attending school in the US, for example, are not equivalent to those in STEM related fields of study and employment.

There are, of course, many issues at play here. And there are also many ways of going about finding a solution. In this section, we aim to show how innovative approaches to teaching and learning are vital if education quality and accessibility is to improve. This is because doing so is a reflective process – one that requires educators to analyse what has and hasn't worked in the past and adjust accordingly. This process is at the heart of change.

We begin by considering some examples of innovative approaches to school-based education. For example, Dr Edmund Gordon and Dr Cynthia McCallister have put forward an approach to classroom education, known as 'Learning Cultures', that integrates assessment for learning and engaging learners in socially-meaningful activities. This enables them to pursue learning goals that flow from their passions, beliefs and desires. Ultimately, this results in more individualised learning and greater equity in education.

Of course, education is not just about academic progress and achievements. It's important that students develop useful personal attributes – some of which will contribute greatly to their success. One such quality for effective problem solvers, rather interestingly, is empathy. Our next article examines the role of empathy in decision making, especially as it pertains to the field of engineering. Past research has found that engineering students graduate with less concern for the welfare of the public, and for the social implications of engineering design. This is an issue because it negatively impacts a student's effectiveness in their careers and what they can achieve for their community. To address this, researchers from the University of Georgia aim to educate students as to how to be aware of the humanistic aspects of working in complex socio-technical systems.

Another example of skills and attributes focused learning is the work of Dr John Coleman at Langston University, Oklahoma. He is developing innovative methods to ensure that students are equipped with two of the most important skills for a STEM career – critical thinking and problem solving. As is highlighted in this article, these skills are also critical to college retention and success. Dr Coleman's program, known as 'Langston's Integrated Network College for STEM', or 'LINC', aims to impart these skills, thus supporting students' long-term success.

We will now shift our focus to educational innovation in more specific college-based educational contexts. Our first port of call will be Dr Lisa Hibbard and her blended and flipped learning approach to first year chemistry classes. In this case, the flipped learning environment is simply described as doing school work at home, and homework in class. But before you sigh and despondently utter the word 'homework' under your breath, class activities in this program are team-oriented, project-based and supported by relevant technologies. The approach is already having a positive effect on student learning and performance.

As another example of innovative approaches to college-based learning, in the subsequent article we'll look as the work of Dr Lisa Dierker and her team at Wesleyan University. They have developed a novel approach to teaching statistics and data analysis that empowers students from diverse educational backgrounds. Their program, known as 'Passion Driven Statistics', introduces students to statistics by focusing on real-world problems, and issues that matter to the students. Students then

become confident in their ability to analyse data and learn to approach problems with a statistical eye.

According to Vítor Correia, president of the European Federation of Geologists (EFG), giving students such hands-on experience with statistics and data mining is essential if we are to address the greatest challenge facing humankind today – climate change. Here we feature an exclusive interview about how the EFG is helping to shape the future of geoscience through education and outreach.

The remainder of this section will focus on some of the ways that data-driven decision making helps to improve STEM education. For example, consider the issue of high dropout rates in community colleges. Dr Lori Silverman and her colleagues at Colytix have developed tools, some of which make the most of mobile technologies, to understand the reasons behind these high dropout rates. They are also seeking to ascertain the non-cognitive factors that influence student success and performance.

Finally, we feature the work of Dr David Williamson Shaffer, who has devised a novel theory and set of techniques for merging quantitative and qualitative analyses to discover meaningful patterns in big data. Using data sets related to teaching and learning, he wants to delineate how and why learning occurs.

As you read through the articles in this final section of the edition, you will notice how innovative approaches to teaching and learning, in both school-based and college-based education, is having a positive impact on student learning, educational accessibility, college retention and career preparedness. You will also notice how such initiatives encourage students to be creative and innovative problem solvers, and to express themselves openly and willingly. And finally, you will see how data-driven decision making and program development is offering additional insights into the way students learn.

CENTRING STUDENTS AND CHANGING THE LANDSCAPE OF CLASSROOM EDUCATION

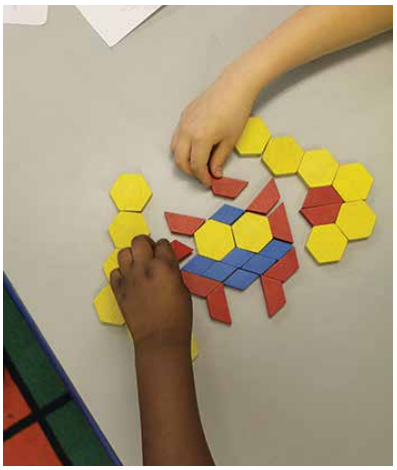
Recent advances in science have demonstrated that human learning and thinking are highly social processes, governed by the learner's ability to manage attention and effort. **Drs Edmund Gordon and Cynthia McCallister** propose an approach to education that centres the student in a dialectical model of pedagogy that integrates assessment, learning and teaching. Within their model, the loci of learning are the wilful, goal-oriented, socially-engaged processes that empower learners to develop intellective competencies.

As rapid developments in technology reshape society, it is critical that educational systems change in ways that offer all students fair access to appropriate and sufficient educational opportunities. For centuries, education systems have been structured around classical transmission views of learning, which portray students as spectators and charge teachers with the primary responsibility for their learning. Teachers provide information, and students learn by receiving it. Within this framework, assessment OF learning has been focused on measuring the end result of the transmission process, rather than capturing the process itself. However, current research in human thinking and learning discredits this model in favour of a more active and social role for learners.

Particularly in STEM fields – science, technology, engineering and mathematics – assessment focuses heavily on evaluating the memorisation of facts, rather than illuminating the mental processes that are associated with the intellective competencies that are an aspect of scientific thinking, such as the ability to engage in logical reasoning, the capacity to appreciate multiple perspectives, the ability to make independent judgements, and the inclination to ask questions to improve understanding. These intellectual competencies prove more valuable than memorisation, and educational programs that nurture these abilities produce independent and capable learners with the capacity to contribute to society at all levels.

Evidence showing that current models often work to perpetuate racial and socioeconomic inequalities between students underscores the need to shift away from traditional educational strategies. Innovative educational systems that capture and build upon diversity within a group of learners, which identify points during the learning process where a shift in teaching strategy could better contribute to intellectual development, are a means to reduce inequalities. Dr Edmund Gordon, a leading expert on issues of race, privilege and intellectual development, has spent his career attempting to both understand the causes of gaps in achievement between disadvantaged and advantaged students, and develop strategies to close these gaps. He has argued that education, to be equitable, should provide every learner with opportunities that are sufficient to enable them to meet high learning standards.

Dr Cynthia McCallister, a protégé of Dr Gordon, has focused her career on developing an educational system that meets this aim. Her model, Learning Cultures (www.learningcultures.net), shifts the dominant teacher-centred paradigm toward a more student-centred model oriented around the social worlds of learners. It is a rich way of conceptualising pedagogy as a dialectical integration of learning, teaching and assessment, engaging learners in socially-meaningful activities and benefiting them at every level of mastery. Learning Cultures activities tap into students' intentional states, enabling them to pursue learning goals that flow from their passions, beliefs and desires. By providing every learner with the experiences that they need to succeed, Learning Cultures creates more equitable conditions for students from disadvantaged backgrounds, and is a promising way to approach the challenge of educational equity.



Inequality and STEM

Among the highest goals of modern education are to level the playing field for students coming from disadvantaged backgrounds, to increase their access to high-quality education opportunities, and to increase diversity in academia and the work

‘Insights from assessments FOR learning can inform both teaching and learning behaviours and transactions as means to improve the cultivation of ability’

force in STEM fields. Despite many efforts to increase participation in STEM fields among diverse groups, dropout rates among women and minorities are consistently higher. Most current educational models fail to assess inequalities at their point of origin when learners experience difficulty in the learning process.

Outside of the classroom, disadvantaged children are less likely to interact with people with academic experience, decreasing the perceived relevance of education in their lives, and reducing opportunities for incidental learning that are often taken for granted in privileged households. These populations frequently have limited access to rich learning opportunities, are more likely to attend under-resourced schools, and have fewer interactions with peers that have more developed academic understanding and vocabularies. In short, they have had more limited opportunities to exchange mental states with others about canonical forms of knowledge that formal curricula are based upon. This last point is particularly relevant to STEM fields, as they have a distinct mode of communication that relies heavily on specialised language, categorisation and logical relationships. This unique way of understanding and communicating about the world is essential to scientific thought, and is best learned through social interactions. Such interactions are often less readily available to disadvantaged children. Students who begin the learning process at a disadvantage due to limited experience depend on opportunities of schooling to close the gap. Dr McCallister’s innovative approach to classroom structure holds the potential to transform modern education in a way that benefits children from all walks of life. Her process involves three critical pieces: assessment and instruction FOR learning, oriented on maturational processes that support development; social collaboration, so that learners may use others as resources for learning; and self-determination, so that learners themselves can become more active and intentional in their learning.

In many ways, school is a child’s gateway into society. It grants children opportunities to develop nuanced social skills, expand their ways of thinking, and gain access to new realms of knowledge about the world at large. When the educational system succeeds, it produces great thinkers and productive members of society. When it fails, it hinders children’s development in both intellectual and social realms, and functions on a broader scale to stratify society. Equitable models of education are especially critical at a time when inequalities are growing at every level of society.

Timing in Assessment

Assessments are critical to evaluating the effectiveness of any learning program. However, traditional educational assessments OF learning, which focus only on the end result – whether the material has or has not been learned – fail to provide information about the pedagogical process and how students and teachers interact to bring about learning. Relying heavily upon memorised material, these assessments fail to provide insight into how students use and develop the intellectual abilities that the educational process is aiming to cultivate. With an exclusive focus on assessments OF learning, teachers are encouraged to teach to the test – seldom an effective strategy for learning and its integration into mental abilities. With a neglect for assessments OF learning, educators miss opportunities to shift teaching strategies and encourage the learning process at critical points of student need. While end-point assessments OF learning might capture a student’s ability to retain information in the short term, they fall short of demonstrating how learners seek to control the mental processes that enable the material to be applied and how teachers support the learning process. Further, assessments OF learning assign students a status level related to how much knowledge they have mastered, reinforce existing inequalities.

Drs Gordon and McCallister propose an assessment system that focuses both on the learning process as well as the ultimate result. Dr Gordon, Chairman of the Gordon Commission on the Future of Assessment (a group of renowned scholars who proposed a vision for assessment that is fair and targeted toward the improvement of the quality of education in the U.S.) advocates process-focused assessments that give students and teachers the opportunity to engage in generative learning – learning that shifts pace and strategy with the unique needs of the students.

Ongoing assessments of the learning process, rather than assessments focused only upon learned material, give educators the ability to describe and shape a given student's thinking patterns. These assessments offer insight into how a student handles new information, takes action and ask questions when they are confused, uses logical reasoning abilities, has tolerance for other perspectives, and exercises their ability to form independent opinions. 'We argue that educational assessments, because they play a critical role in shaping and influencing educational contexts as well as outcomes, can be deployed to catalyse the learning process, helping to bring about the very processes and outcomes they are designed to measure,' says Dr Gordon.

Social Learners

The cultural transmission of knowledge – the ability to share knowledge and learn from others without directly experiencing the source of knowledge – is one of the most unique and special human traits. Social collaboration – the ability to collaborate with others to solve a problem as a group – is likely one of the cognitive adaptations that has allowed humans to evolve into such an innovative and pioneering species. The competencies that enabled our distant ancestors to collaborate to survive are the same that enable thinking and problem solving in modern humans. It appears our brains are uniquely wired to acquire and process information best in social contexts.

The same is true of children in learning situations – social collaboration can be harnessed to empower learners to work together to form a comprehensive understanding of material through supervised dialogue with fellow students. By discussing points of confusion, filling in one another's gaps in understanding, and building from each other's unique experiences and perspective, people working as a team are often able to synthesise information in a deeper way and develop fresh ideas and solutions. When individuals work cooperatively with others to solve a problem, they often learn far more and come up with more novel solutions than if they had attempted the same challenge on their own.

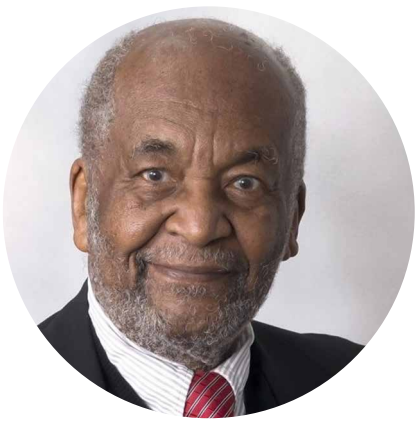
Unlike the classical transmission model of teaching, where the instructor presents material with limited interchange between students, social collaboration provides benefits to students at all levels of mastery. Students with a strong command of the material reinforce their knowledge, develop depth of understanding, and cultivate social-emotional competencies, while weaker students gain clarification specific to their questions and develop confidence articulating the material. Further, as inherently social animals, we crave attention and engagement with our peers, and so these interactions are met with much higher motivation and enthusiasm than being called on in class by a teacher.

Self-Determination

Despite being highly social creatures, humans also possess a strong drive for autonomy. We are motivated to act when we feel in control of our lives, and quickly grow despondent when we feel helpless to influence our situation. Traditional educational environments place the responsibility for learning in the hands of the teacher, treating education as a temporary intervention in students' lives, rather than a lifelong process motivated by the student. This is reinforced by assessments that focus material at an end point, rather than using assessment to provide an opportunity to correct and clarify misunderstanding during the learning process. This is particularly important for disadvantaged youths, as those who do not feel in control of their educational outcomes are much more likely to perform poorly in their learning endeavours.

Dr McCallister's Learning Cultures system instead works to cultivate self-determination and individual responsibility in students. Students are given a framework, materials, and curriculum objectives, and encouraged to work towards their learning objectives at their own pace, utilising social collaboration to reinforce and expand their understanding of the concepts they are learning. This framework gives each student agency over their own education, while still offering enough structure and support to ensure that material is completed. In our modern environment of near constant information overload, the ability to self-regulate is perhaps one of the most critical competencies a student can learn. The Learning Cultures system facilitates autonomy and self-organisation in a manner that engages and motivates all students, including those from diverse backgrounds.

The relationship between diversity of perspectives and the advancement of knowledge in a field cannot be underestimated – when people from diverse circumstances work together on a problem, their unique perspectives build upon one another and converge into a more profound solution than any one person could ever devise on their own. STEM fields tackle humanity's largest problems, and solving our paramount challenges demands teams of intellectuals from varied backgrounds to collaborate for the greater good. Drs Gordon and McCallister propose an approach to education that creates a more equitable environment for learning in STEM, while simultaneously cultivating strong communicators, critical thinkers, and self-driven learners.



Meet the researchers

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Dr Cynthia McCallister began her education at Ball State University with a Bachelor's in History and Political Science. She continued on to complete her Master and Doctor of Education degrees at the University of Maine, specialising in Literacy Education. She joined the in the Department of Teaching and Learning, in the School of Education at New York University in 1998, where she currently serves as an Associate Professor. Over the last two decades, working in high poverty New York City public schools, she pioneered Learning Cultures® – a comprehensive education model that has transformed numerous New York City elementary, middle and high schools into some of the top performing schools in the city.

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Dr Edmund Gordon began his education at Howard University, obtaining Bachelor's degrees in both Zoology and Social Ethics. He continued with a Master in Social Psychology at American University, completed training in Psychotherapy at New York Medical College, and ultimately received a Doctorate in Education from Columbia University in 1957. During his distinguished career, he has published over 200 papers and 20 books, mentored countless students, and served as a pioneer of equality and reform in education. He currently serves as a John M. Musser Professor of Psychology, Emeritus at Yale University and as the chairman of the Gordon Commission on the Future of Assessment in Education, devoted to leveraging assessment technology to develop effective teaching methods.

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FOSTERING EMPATHY IN ENGINEERING EDUCATION

Past research has found that engineering students graduate with less concern for the welfare of the public, and for the social implications of engineering design, than when they begin their studies. To address this issue, researchers from the University of Georgia have developed a theoretical model of empathy in engineering to provide a foundation for systematic research in this area, to inform pedagogical innovation, and to potentially impact the culture of the engineering profession in a way that incorporates a fundamentally different understanding of empathy.

The Importance of Empathy in Engineering

Loosely defined, empathy can be understood as the capacity to understand and share the feelings of others, and adequately respond to them. It is a form of social reasoning that enables one to imagine 'walking a mile in someone else's shoes', experiencing another's emotions, ideas, or opinions, without judgment. Empathy is often believed to be one of the key qualities for professional success in many, if not most, fields.

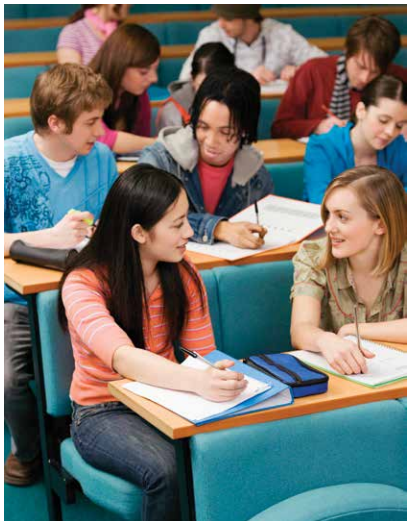
As the pace of technological and scientific advancement accelerates, it is becoming increasingly crucial for engineers to be empathic and attuned to the needs and experiences of a diverse range of stakeholders, including those who are directly and indirectly affected by their designs.

Engineers who excel in technical and social forms of reasoning are emerging as important industry leaders. Lisa P. Jackson, for example, past head of the US Environmental Protection Agency and current vice president of Environment, Policy, and Social Initiatives at Apple, attributes her career success to her early ability to both solve technical problems and effectively engage with members of the general public. Similarly, a study carried out by Google found that the best performing engineering teams were those that had high levels of 'social sensitivity' – a term that refers to the ability to pick up on and respond to the feelings and viewpoints of others. In the US, the Code of Ethics for Engineers specifies that professionals operating in the field should 'hold paramount the safety, health, and welfare of the public'. In other words, to adequately fulfil their duty, engineers are expected to be empathically aware of society's needs, carrying out their work with these in mind.

However, research has found that, over the course of their education, many engineering students tend to gradually cast aside their concern for the welfare of the public, and for understanding how people use and may be impacted by technology. This trend has been attributed to engineering education's relentless emphasis on solving technical problems, and the corresponding lack of focus on non-technical skills, such as ethical reasoning and empathic perspective taking.

Acknowledging the importance for engineers to develop both technical expertise and empathy-related skills and dispositions, many engineering programs have increased their focus on communication, teamwork, and interdisciplinary collaboration. However, course material specifically fostering empathy is still less common, possibly due to the lack of a coherent framework that defines and contextualises it in relation to the field of engineering.

So far, efforts to introduce empathy in engineering education have varied from immersive design experiences – connecting students with users they are designing technology for – to broader examinations of empathy in relation to engineering ethics, which ask students to consider the perspectives of those who are not present and incorporate these into their reasoning process.



The field of social work, in which empathy plays a key role, offers a range of theoretical frameworks and pedagogical approaches designed to foster empathy in students, preparing them for their professional practice. If appropriately adapted to fit engineering contexts, these frameworks could also be applied within engineering undergraduate programs.

By merging such social work frameworks and engineering concepts, a group of researchers at the University of Georgia has now developed a new theoretical model for empathy in engineering. The model defines empathy as a skill, orientation, and professional way of being. In addition to its other applications, the team has used their model to design a set of in-class activities to foster empathy in undergraduate engineering students.

The Empathy Project

In 2012, the University of Georgia established a new College of Engineering, aimed at educating students on how to be not only technically excellent, but also innovative and aware of humanistic aspects of working in complex socio-technical systems. This led to the development of new curricula for the College's eight undergraduate programs, which are designed to train engineering students on both technical and socially-relevant skills.

The Empathy Project is an interdisciplinary collaboration between engineering and social work educators, which addresses the increasing emphasis on how essential empathy is for effective engineering practice, and the related growing need to enhance empathy among engineers.

The primary researchers involved in the project include Dr Joachim Walther, associate professor of engineering education, Dr Shari Miller, associate professor and associate dean of the School of Social Work, and Dr Nicola Sochacka, research scientist in the CLUSTER research group at the University of Georgia. By sharing their diverse knowledge and expertise, these researchers aimed to develop a context-appropriate and conceptually cohesive way of applying empathy to engineering-related settings, and informing the culture of the profession.

A Model for Empathy in Engineering

The theoretical model, and related empathy modules delivered at the University of Georgia, are the product of a six-year collaboration between Drs Walther, Miller, and Sochacka. Complementing and expanding previous research efforts, the team's approach views empathy as central to both the design process and broader engineering practice. The team's model defines empathy as a skill, a practice orientation, and an overall professional way of being. These three dimensions are mutually dependent, supporting each other without a specific hierarchy or developmental trajectory. The researchers suggest that empathy, understood in this way, can be developed in students through educational approaches that draw on their innate empathic capacities.

The 'skill' dimension is adapted from Decety and Morigucci's (2007) model, which delineates four distinct socio-cognitive processes. The model adds a fifth process, and suggests that the combination of all five forms the foundation for an individual's capacity for empathic communication, relationship building, and decision making. These processes include affective sharing (the ability to share another's emotional state), awareness of self and others, seeing someone else's perspective, regulating emotions, and mode switching – the ability to switch between empathic and analytic skills in given situations.

The 'orientation' dimension includes a series of mentalities that affect how engineers approach practical situations, prompting them to empathically engage with others. For instance, openness predisposes engineers to be aware of and value the perspectives of others participating in, or affected by their work. Other orientations are related to productively working across the micro to macro spectrum when developing technology, considering others affected and the surrounding context, being reflective, and valuing diverse perspectives.

Finally, the 'being' dimension is related to the application of empathy skills and practice orientations in a broader commitment to oneself, society, and the natural environment.

Applying the Model to a Mechanical Engineering Course

After developing their theoretical model, the researchers applied it to a mechanical engineering class offered at the University of Georgia, in the form of in-class activities aimed at helping students to relate more empathically with others.

The Engineering and Society class for mechanical engineering students at the University of Georgia involves a series of group-based design challenges that ask students to frame problems within complex, socio-technical contexts. The four empathy modules for this class aim to provide students with 'contextually relevant

opportunities to experience and explore the entire conceptual space of empathy as a skill, practice orientation, and way of being', in ways that enable students to later apply what they learned in their work.

Each of the modules includes a set of structured exercises that are drawn from pedagogical traditions in social work, adapted to fit the engineering context. These modules focus on the following topics: encountering others with genuineness, self-awareness and emotion regulation, affective responding, and synthesising prior exercises while learning to switch between analytic and empathic modes of communication.

The students complete group activities related to body language, proximity, or communication, and are given examples of real-life scenarios to practice their skills in an engineering-related context. After each module, they are asked to write guided reflections about what they have learned, prompting introspection and consolidation of the main learning outcomes.

Student Responses to the Modules

Throughout the modules, the researchers collected student accounts about their experiences. They also made classroom observations and acquired feedback from instructors. These data were later used to conduct research on students' engagement with the new course material, as well as how they came to understand the role of empathy in engineering through the class experiences.

To examine students' interpretations of empathy in engineering, the researchers used Alfred Schutz's social phenomenology framework, which focuses on intentional relationships, or meaning making in interactions, with other humans and with non-human objects, placing them within a meaning-context. Intentional relationships observed in the collected data were placed into three categories: those between the Self (i.e. the students) and Learning, the Self and Others, and the Self and Content.

The students reported experiencing varying levels of disconnect between their expectations of what an engineering learning environment should be like and the exercises they completed as part of the empathy modules. Some students were able to accommodate these experiences, while others found it hard to reconcile them with what they assumed engineering education should be like. In terms of their relationship with others, students' accounts were very complex and diverse, relating to both others in the classroom and non-present 'others'.

One student who participated in the empathy-related modules said: 'It seemed like you didn't want us to solve the problem and just make small talk', expressing a perceived dissonance between what he felt an engineering class should convey and what was covered by the modules. While some students struggled with the empathy exercises, many felt that they had somewhat challenged their views, prompting them to engage with other people's perspectives, consider their feelings, and observe the bigger picture.

In a post-module reflection, another student wrote: 'As an engineer, this activity made me realise how important listening can be. Engineers are required to communicate well, and this means more than just working around problems. With attentive listening, responses come naturally, and in the future I will try to be a better listener rather than just a problem solver.'

Fostering STEM-Related Skills

Drs Walther, Miller, and Sochacka's research has important implications for engineering education, highlighting the potential benefits of integrating empathy-related material within engineering courses.

Teaching engineering students how to be empathic could ultimately help them to develop a more ethical, aware, and responsible approach to their profession, which takes into consideration greater socio-economic contexts as well as the perspectives of non-engineers. This could be highly beneficial, as the work of engineers does require excellent technical preparation, but it also hinges upon understanding the actual needs and circumstances of people in society, upon whom their work will ultimately have profound impacts.

Moreover, empathy can facilitate communication with colleagues and collaborators, encouraging more constructive and mutually understanding relationships that will help students to thrive and make the most out of their future work opportunities. Empathy then will also serve to enhance the effectiveness and productivity of teams in the workplace, which can be of great utility to industry.

So far, the empathy project at the University of Georgia has shown promising results and has already served as an example for other educators and academic programs hoping to foster empathy within service-learning and medical-engineering settings.

The researchers have also written several papers about their work, trained other educators on how to apply the modules, and organised engagement activities that prompt further discussion about teaching empathy in the context of engineering.

In the future, Drs Walther, Miller and Sochacka plan to prepare 'how-to' guides for the implementation of their theoretical model in the classroom and organise workshops that encourage further conversations about and research on empathy in engineering.

Meet the researchers

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Dr Nicola Sochacka is the associate director of EETI and co-leads the engineering education research CLUSTER at the University of Georgia (http://education.engineering.uga.edu/). Dr Sochacka's highly interdisciplinary research program is underpinned by a deep appreciation for different worldviews. She works closely with colleagues from across multiple engineering disciplines, as well as the arts, social work, and education on projects related to institutional change, STEAM (STEM + Art) education, empathy, diversity, and reflection. Dr Sochacka's work is supported by over 1.7 million in grant funding, and has been recognised through multiple invited keynote presentations and best paper awards at international and national conferences.

Dr Joachim Walther is the founding director of the Engineering Education Transformations Institute (EETI) in the College of Engineering at the University of Georgia. He conducts research in engineering education and has received over $2.5 million of funding in this area. Dr Walther co-leads a dynamic interdisciplinary research group that brings together professors, graduate, and undergraduate students from engineering, art, educational psychology, and social work. His work has been recognised through numerous university-level, national, and international awards. Most notably, Dr Walther is a recipient of the Presidential Early Career Award for Scientists and Engineers (PECASE), the highest honour bestowed by the United States government on science and engineering professionals in the early stages of their independent research careers.

Dr Shari Miller is the Associate Dean in the School of Social Work at the University of Georgia. She conducts research related to professional education for reflective and effective practice in a sustainable local and global society. Dr Miller's research more specifically focuses on social work education and the culture of the profession, while also placing strong emphasis on inter-professional and trans-disciplinary collaboration in research and in educational innovation. She has garnered over $4 million in research and training grants in this area, and her work has been recognised through a number of university-level and national fellowships and awards.

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FOCUSING ON THE PROBLEM IN STEM EDUCATION

The modern workforce needs to be more science educated than ever, yet the number of students in higher education enrolled in scientific subjects has not increased. **Dr John Coleman** at Langston University, Oklahoma, is developing novel methods for teaching scientific concepts that engage students in critical problem-solving skills. His research is increasing retention in scientific undergraduate degrees and is laying the groundwork for a transformative method of science teaching.

Science, technology, engineering, and mathematics (STEM) fields are in higher demand than ever in the modern workforce, and a diverse population of qualified STEM workers is critical to the long-term economic development of the United States. As technology changes at a breakneck pace, more and more non-STEM employers are recruiting STEM candidates to help their businesses keep up.

The core competencies of science degrees – critical thinking and problem solving – are recognised as beneficial across fields. The US is facing a shortage of qualified employees, as non-STEM industries are looking to hire STEM-trained workers. Without increased levels of participation in science, math, and engineering in colleges across the nation, the country will be less able to compete in increasingly technology driven global markets. There are a number of causes for this shortage. One is that only a small percentage of students choose to pursue STEM degrees, and STEM students in general have higher rates of major subject changes and drop-outs. Another reason is more insidious – many high schools do not offer advanced STEM courses such as chemistry, calculus and physics and science teachers are neither STEM majors or STEM certified.

These problems are particularly pronounced among minority students – African-American students are highly underrepresented in scientific fields, and a higher participation of this group will be required to meet anticipated demand. Lack of interest in STEM subjects across demographics is attributed to many factors, including a lack of awareness of career potential, a perception as unpopular subjects, poor preparation in core courses, and a lack of mentors, particularly representative mentors for minorities and women.

Dr John Coleman and his team at the historically Black Langston University in Langston, Oklahoma, are studying interventions that help keep students studying STEM subjects and can support them in the transition to advanced degrees and teaching careers with their specialised knowledge. Working with an interdisciplinary team of educators and scientists he is evaluating ways to retain students in STEM subjects and encourage more science and math graduates to enter the workforce as teachers in order to strengthen the potential STEM pool.

Improving Preparation for STEM

To help keep first year college students studying science and math, Dr Coleman recognised a need to approach teaching differently. Most incoming STEM students have not received solid foundations in the ability to think and problem solve like a scientist, rather they have been taught science in a way that rewards memorisation without critical thinking. For decades less than 30% of high school graduates have demonstrated readiness for college level courses, according to the ACT (American College Test) reports. That trend continues through to the present. This lack of preparation is a major factor in the number of students that change their degree out of STEM courses in their first year. To help solve this problem Dr Coleman realised that foundation level STEM courses in college need to integrate learning analytical processes and also promote a community experience.

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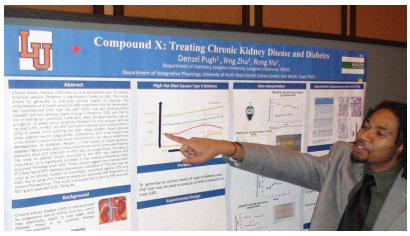
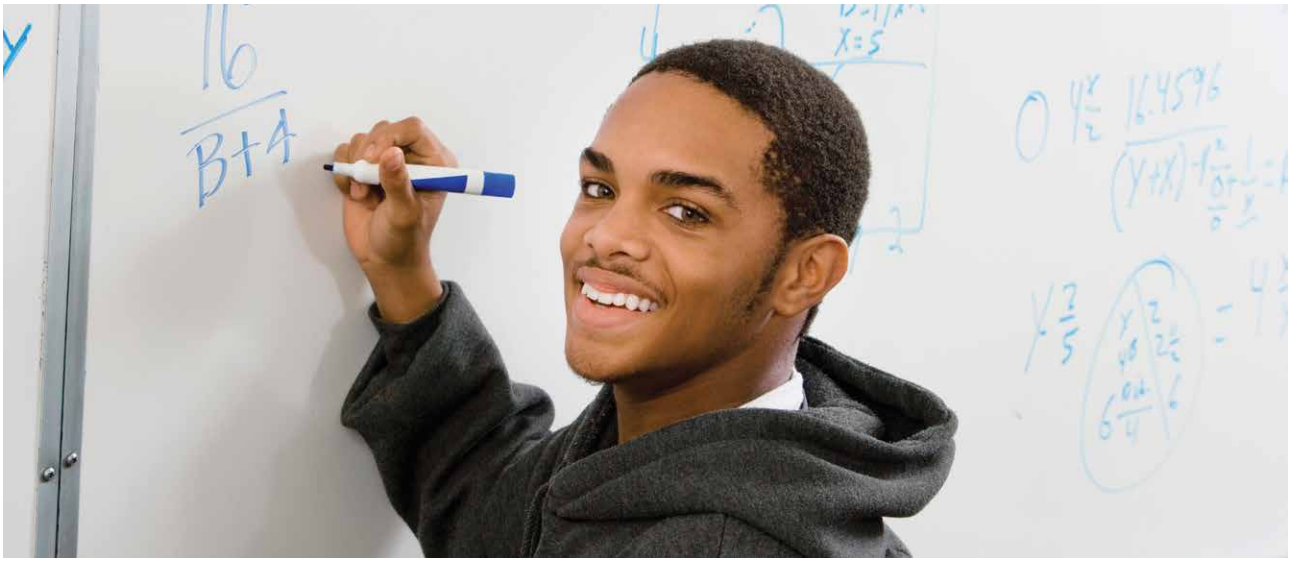


The US National Science Foundation (NSF) recognises this as a national phenomenon and awards grants to deserving institutions aimed at developing solutions. In support of this goal, in 2003, Langston University was awarded NSF funding to increase STEM enrolment and retention, and to increase the number of students that would continue on into related graduate programs. This was the formal beginning of Dr Coleman's work in this area. His program, Langston's Integrated Network College for STEM (LINC), was formed to recruit predominantly African-American students into science and math, and to support their educational journey throughout their college career. It was apparent that to increase the potential of the STEM pool, issues identified by the NSF and anticipated deficiencies had to be addressed head-on. During the ten-year period of the LINC program, as well as concurrent years

‘My work as a college level STEM educator seeks to displace bad habit methods such as the “plug and play” approach that only works when problems mirror given examples.’



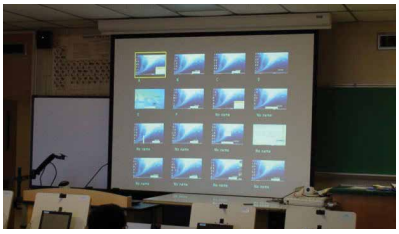
of pre-college math and science programs for Oklahoma high schoolers, researchers dove deeper with student interviews and test analysis, finding key patterns that resulted in poor performance in STEM courses.

Dr Coleman explains that: ‘The most critical issue that impedes college bound students’ ability to adopt a logical, problem-solving process that ensures success in STEM courses is their extreme lack of foundational knowledge. Our research findings at LU and at other institutions where I taught college level STEM courses showed that students consistently identified their previous failed learning methodologies as “plug and play”, “work-arounds” and “pattern-matching”, too many multiple-choice questions on tests (instead of word problems) and lack of knowing how to look at a problem in pieces rather than looking at the “whole pie”. Their “pattern-matching” involved selecting the mathematical format from a “similar” problem that was solved and matching their corresponding numbers in appropriate slots to obtain answers and in some instances manipulating their numbers to get a correct answer, paying little or no attention to the “whys”. Knowledge of core course concepts, the capacity to comprehend reading problems, or following scientific processes to solve problems did not appear to be relevant because teachers only required that they get the “right” answer. Colleagues throughout the US reported observing similar learning dysfunctions. It was clear that these approaches to learning had to be excised because they seriously inhibit students’ ability to acquire subject matter excellence, and unless corrected this jeopardises the nation’s ability to produce competent STEM professionals capable of contributing to the next big discovery, or even training the next generation of capable STEM teachers.’

At the start of the program, some of Langston’s introductory STEM courses had average pass rates under 40%, a performance that mirrored many institutions across the US. To help start STEM students off on the right foot, the LINC program started providing a four-week summer bridge program for incoming freshmen interested in STEM subjects as their major discipline. This program offered immersive classes in calculus, chemistry and biology to help prepare students for their upcoming coursework, a process that radically improved their grades by the end of the session. Additionally, students accepted into the LINC program were provided with faculty and peer mentoring throughout their college years. They were also given access to the STEM Digital Village, an online repository of personal development tools, internship opportunities, graduate school preparatory materials, and other supplements to their mentoring and classroom experiences.

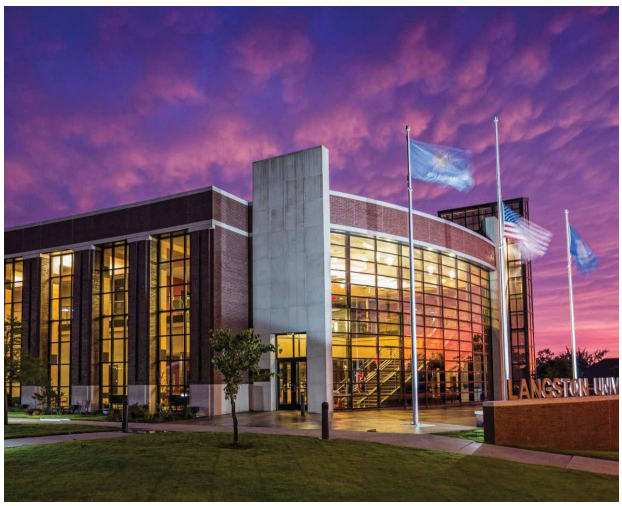
Retaining Students in STEM Through Better Coursework

Dr Coleman saw an opportunity to alter how first year students approach solving complex problems, to disrupt their propensity to memorise answers. His process, Competency Performance Recordings for Learning (CPR-L) focuses on honing cognition skills. Further, it uses proven methods to help students learn how to think more like scientists, utilising multiple modes of learning to increase retention of core concepts, helping students understand how these concepts are connected and cultivating critical thinking skills.



CPR-L focuses on the problem-solving process as a whole. Course rubrics guide students as they learn to articulate a problem by expressing the knowns and unknowns, then they select the appropriate equation or algorithm based on the values they have, and the one they wish to find. Finally, students apply the equation or algorithm to solve the unknown value. They are required to narrate their process of solving the problem, recording their voice and handwriting as they proceed. Students expect that it will require an iterative process before their recorded solution is sufficiently correct to be reviewed.

CPR-L’s process of identifying underlying course concepts – giving voice to students’ understanding of those concepts within the context of the problem presented, hearing their proposed solutions spoken out loud, and the iterative nature of developing a clean, succinct recording – can engage multiple proven learning channels and



support retention of the material in a contextual way. Further, the audio/visual recording supplies a record of the student's understanding and confirms that the student was a primary participant in the process. In some cases, the student's recording forms the basis for classroom discussion – the mere fact that a peer produced the work appears to engage the class in a meaningful way.

Dr Coleman describes how: 'My work as a college level STEM educator seeks to displace bad habit methods such as the "plug and play" approach that only works when problems mirror given examples. In its place I have developed a method of teaching problem-solving that forces student engagement through its reading and rereading process to dissect the problem construct; the requirement of research and identification of underlying concepts; and physical evidence of process compliance and engagement. As importantly, the CPR-L method aids in identifying the specific steps that hindered a student from successfully applying the problem-solving sequence. The highly defined process involves learning that seeks a solution to a problem and articulates that solution as if the student were teaching the process to others, rather than seeking a "right" answer or memorising facts to pass a test. Initially, the CPR-L application is disruptive, as it interrupts prior dysfunctional learning. Although rigorous, most students master the process and find that it enhances their ability to solve other problems. The application of this CPR-L process provides students with skill sets that can be applied at all course levels, from pre-college to advanced courses and across disciplines. If applied at all pre-college grade levels, this learning methodology could play an important role in mitigating the development of bad learning habits. The LINC program results demonstrate the effectiveness of the strategies utilised, as STEM enrolment increased substantially, and the rate of retention through graduation and the number of earned advanced and professional degrees (92.5% and 69%, respectively) far exceeded national norms.'

Addressing Pre-Collegiate STEM Education

Another key component of addressing the STEM educational gap is ensuring that students receive a better quality of preparatory education before starting college. Many US middle and high school STEM teachers are not formally trained in science and are often reliant upon limited access to development and training opportunities to gain the knowledge needed to provide a high-quality STEM education. One potential solution that has received recognition is to increase the number of STEM graduates that go on to pursue careers in teaching. In 2014, Dr Coleman and his team set out to develop a program to help funnel higher numbers of STEM graduates into high school teaching positions. Funded by the National Science Foundation's Noyce STEM Teacher Scholarship Grant, the team developed a comprehensive program to recruit, mentor, and guide STEM students with an interest in education to teaching positions.

Induction into the program begins with a rigorous recruiting and interview process, targeting STEM undergraduates who express an interest in teaching, as well as high performing students who have yet to decide their major subject area. Candidates participate in an interview with STEM and Education faculty and the accepted candidates work with faculty to develop a comprehensive academic action plan. Students are assigned both faculty and peer mentors who are trained in effective mentoring and are able to provide tutoring and guidance at every stage of college progression. Program students also participate in research internships and STEM and Teaching Certification workshops and enjoy the same access to the STEM Digital Village data library as LINC participants. These students are also enrolled in courses that utilise the CPR-L process and are given exposure to the tenants of effective science teaching.

The effects of the program have been positive. So far, LU has more than quadrupled the number of STEM teacher candidates, and the program is demonstrating success in preparing teacher candidates for overall excellence. However, while the students in the program are more likely to stay in STEM subjects and graduate, many ultimately choose not to pursue teaching as they reach their final year of coursework and realise other potentially more profitable career paths are available to scientists and engineers. A penalty clause that requires repayment of any Noyce funds utilised does not dissuade some of them.

Interviews with program participants often indicate that teacher salaries are not competitive with other STEM employment options, nor do they seem worthwhile for the work involved in obtaining a STEM degree. Dr Coleman elaborates that, 'as long as unqualified personnel are allowed to teach in such critical and skill-intensive disciplines as STEM at the pre-college level, the quality of the future STEM pool will continue to erode. Further, if this situation persists salaries will never rise to meet the demand for competent STEM teachers at this level. This also jeopardises the nation's ability to produce competent STEM professionals.'

The Future of STEM Education

Dr Coleman is already working on the 'next steps' that can positively influence undergraduate STEM students and future STEM teachers. He is working collaboratively with other STEM professors to develop core course concept rubrics unique to each course. These rubrics, when followed by teachers, present a clear blueprint for course content presentation that includes the 'why' and 'how' of each core concept, complete with examples of the rubric's contextual applications. When followed, these rubrics will help address the problem of students not receiving adequate instruction and can contribute to students' higher degree of understanding of STEM course concepts and their applications. Dr Coleman is also converting his teaching and learning process into a book aimed at making review and application of his work available more broadly.

Meet the researcher

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Dr Coleman is Chemistry and Physical Sciences Department Chairperson at Langston University. He is also Associate Professor, and Principal Investigator/Director for Langston's Integrated Network College (LINC) for Science, Technology, Engineering and Mathematics (STEM), a National Science Foundation (NSF) Grant supported program. Dr Coleman is Principal Investigator/Director for another NSF supported program at Langston, Noyce STEM Teacher Scholarship program. Since joining Langston University in 1993, Dr Coleman has impacted the institution's future science professionals through his innovative approach to instruction and mentoring, with profound positive impacts. His achievements include leading the creation and operation of several innovative programs that include Competency Performance Recordings for Learning (CPRL) and the STEM Digital Village. His work has been meticulously documented and featured in international and regional publications. Dr Coleman's doctoral thesis and research is in Theoretical Physical Chemistry, and the Molecular Orbital and Structural Investigations of Substituted Cyclobutanediones. His previous experiences include teaching STEM courses in the New York and New Jersey higher education systems and work as an industrial chemist at a major international corporation in the oil industry.

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US National Science Foundation
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ACTIVELY LEARNING CHEMISTRY: BLENDED CLASSES FOR FIRST YEAR COLLEGE STUDENTS

Flipped learning is an exciting new educational strategy aimed at maximising learning by delivering the content of courses online, while focusing classroom time on student-centred active learning tasks. **Dr Lisa Hibbard** at Spelman College in Atlanta, GA has been testing new flipped learning strategies for first year General Chemistry classes which are positively perceived by students and result in better performance.

An Active Way of Learning

Technological tools such as computers, laptops, tablets, and smartphones have officially made their way into a growing number of societies worldwide, changing the way in which we communicate, work, and acquire new information. Technology is also finding its place in educational spaces, with several colleges and universities worldwide delivering blended courses that combine face-to-face and online learning strategies. Using technology and online academic tools, many students can now easily access and read course material remotely, opening up new possibilities for teachers in terms of their use of classroom time.

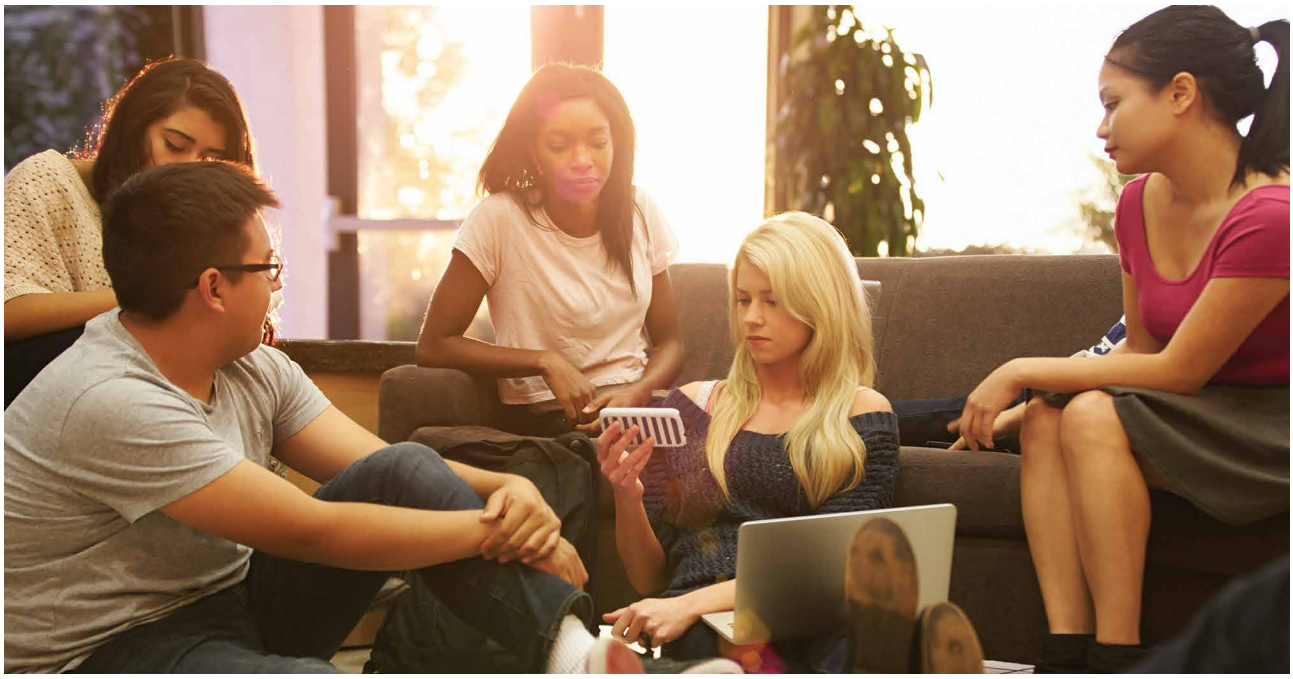
Blended learning strategies aim to make the best use of technology-based educational tools, by devising reasonable models that integrate them with traditional education, or introduce entirely new activities to replace conventional classroom practices. Flipped or inverted learning is a particular type of blended instruction that aims to maximise learning of a particular subject by having students acquire the course content online from home and then focusing classroom learning on other student-centred activities, specifically developed to reiterate acquired concepts.

The idea of moving course material learning outside the classroom and bringing more engaging student activities into the class has been around since the 1990s. Yet, in recent years, this concept was developed further, thanks to the advent of new advanced technological tools that can better support the remote part of these learning strategies. Jonathan Bergmann and Aaron Sams were two of the first to develop and introduce inverted or flipped learning strategies. These two instructors recorded online lectures for their high school chemistry courses and published their observations in a book called *Flip your classroom: reach every student in every class every day.* Their work inspired a number of others, who also created blogs, publications and websites to provide guidance and suggestions on the best flipped learning practices.

So far, flipped learning has been applied to a wide variety of different courses and subjects, each of which differs greatly according to the specific topic's requirements, learning objectives, and the amount of face-to-face learning required, as well as the technology available at a particular institution. What these courses have in common, however, is that they are all centred on the idea that having students independently acquire the course knowledge remotely and using classroom time for more interactive and engaging subject-related activities might improve students' performance and confidence with the subject studied.

Growing evidence has found that, when thoughtfully developed and applied, the flipped learning model leads to higher levels of student performance in tests assessing their knowledge of the subjects studied. Other reported benefits of this new educational strategy include a more efficient use of class time, increased student engagement, an increase in student-teacher and peer interactions, as well as students taking greater responsibility for their own learning.

‘The most important aspect of this teaching strategy is that students become more involved in their own learning process.’



Technology-enhanced Education

Flipped learning has a large technology component to it due to course material being made readily available to students online. Technology-delivered content and assessments may be termed ‘semi self-paced,’ as they allow students to review course materials and self-assess learning at their own pace while concurrently moving through more structured in-class sessions. This sense of empowerment and independence in their learning is seen as one of the most innovative and advantageous aspects of flipped learning, separating it from other more traditional educational models that only require students to attend classes and complete standard homework assignments.

Flipped learning models also provide formative assessments that can be completed using online platforms, through Learning Management Systems (LMSs), or using in-class technology. These assessments often give students immediate feedback, allowing them to identify any unclear subject areas before class so that class time can be used for asking their teacher for further clarification. By using technology to deliver the course content and encouraging students to independently identify those subject areas they might need to work on, teachers can use the time in the classroom as an interactive space that further reinforces what the students learned, while stimulating their critical thinking and inquiry skills.

Flipped Chemistry Learning at Spelman College

Dr Lisa Hibbard, who has been teaching chemistry for several years, recently developed a flipped learning method and started testing it in classes at Spelman College, historically a college for women of African descent, in Atlanta, Georgia. ‘My chemical education research focuses on using active learning techniques in a flipped learning college introductory chemistry course sequence,’ says Dr Hibbard. ‘The flipped learning environment is simply described as doing school work at home, which leaves time to do homework in class.’

The department of chemistry and biochemistry at Spelman traditionally offered three different course sections of General Chemistry I in the first semester and three sections of General Chemistry II in the spring semester, with enrolments of approximately 40 students per section. In the academic year 2012–2013, the college’s first year chemistry course was revised, using Dr Hibbard’s flipped learning model, which introduced new pre-class, in-class and post-class activities, many of which are delivered online or using technological tools.

‘Students are expected to review instructor-narrated lectures online and complete textbook reading assignments prior to attending class,’ Dr Hibbard explains. While completing pre-class readings and watching the lectures, students are asked to take notes, which are then briefly checked by the teacher during class. The topics covered in the pre-class material are then tackled in the classroom in the form of problem-solving sessions, case studies, or mini-projects. ‘Face-to-face class time involves using a variety of active learning methods involving team-based activities,’ says Dr Hibbard. ‘These allow students to teach and learn from their peers while the instructor clarifies any misconceptions on the material covered.’ Team-based learning activities are often structured, with team members taking on specific roles. Since participation is an important aspect of the flipped learning environment, teams are continually asked questions to test their understanding of the subject, receiving participation points when they are able to answer them correctly.

Classroom activities are also sometimes delivered using technological tools, such as iPads with educational apps that allow for simulation and molecular modelling. The preparation and subject comprehension of students is often assessed during class by using quizzes that require students to give their answers through the use of

personal response systems or 'clickers.' This allows the instructor to provide immediate feedback to the students and can also be used as a jumping-off point for further classroom discussions.

The model devised by Dr Hibbard also entails the completion of a series of post-class tasks, delivered using a digital learning environment and an adaptive learning system, called LearnSmart (published by McGraw-Hill Higher Education). LearnSmart allows students to assess their understanding of topics and identify potential knowledge gaps or subjects they might need to revisit before exams. Homework is assigned and submitted through McGraw-Hill's Connect system and other post-class assignments are also submitted via the course learning management system.

An Effective Educational Strategy

After running this flipped learning program for three academic years, Dr Hibbard carried out research assessing its efficacy, both in terms of student satisfaction and their performance in tests. The students' performance was tested throughout the year during in-class and online assignments, as well as in final American Chemical Society standardised exams. The scores of students who completed the flipped learning general chemistry course were compared to those of students who had taken a more traditional course at the same college.

Students who took part in the inverted learning course were also asked to complete a motivation and learning perceptions questionnaire and a blended learning survey, to get a feel for their overall satisfaction with the new learning model. Dr Hibbard's findings suggest that the new inverted learning strategy improved first year students' performance and enhanced their feeling of being able to do well in the course.

Students' perceptions of the new teaching model were mostly positive and revealed a good level of confidence in the subject and sense of responsibility in studying independently.

Dr Hibbard says, 'The most important aspect of this teaching strategy is that students become more involved in their own learning process.' The new model also appeared to increase the retention rate of students who continued studying chemistry and biochemistry after completing the first-year course. In the three years before the new course was introduced, 33.6% of students changed their major after taking the first-year chemistry modules. After the implementation of the flipped learning format, this number decreased to 20.7%.

Dr Hibbard suspects that the blended learning technique might also result in students better retaining the knowledge they acquired over time. She is developing assessment tests for the students continuing their chemistry studies at Spelman after the first year, which should help to understand how well the students who participated in the flipped learning course retain knowledge.

A Glance to the Future

Initial trials of Dr Hibbard's flipped learning model for first year chemistry students have achieved extremely promising results. Students who took the course feel more confident in their ability to achieve good results, while the more interactive use of classroom time resulted in a better grasp of covered subjects and better performance in tests. The educational research carried out by Dr Hibbard led to findings that support existing evidence of the efficacy of thoughtfully developed flipped learning programs, in improving both students' performance and their feelings of self-efficacy.

This suggests that when properly integrated into college or university courses, new technology such as online education platforms, iPads, and learning materials to be accessed on computers, can enhance learning and student motivation. As technology evolves and takes an increasingly prominent role in individuals' everyday life, education is likely to also keep evolving, finding new ways to best support new generations in their acquisition of new knowledge and skills.

Flipped learning and blended educational models, such as the one implemented by Dr Hibbard at Spelman College, are particularly promising strategies, which could inspire a growing number of academic institutions to introduce more contemporary and effective courses for current and future generations of students. Dr Hibbard is still conducting research to further evaluate the effectiveness of the flipped learning module she devised for first year chemistry students at Spelman College.

'I am currently working on a project studying student interaction in a team-based learning environment in the general chemistry course sequence at Spelman College,' she explains. 'I am looking at student behaviour, effort, motivation, and cognitive engagement in order to identify those traits that reinforce learning and promote efficacy.' Dr Hibbard hopes to later use the information she has collected to revise and improve the general chemistry curriculum further, with the aim of promoting even more effective learning.

Meet the researcher

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Dr Lisa Hibbard is an Associate Professor of Chemistry at Spelman College in Atlanta. She completed her studies at the Georgia Institute of Technology, attaining a BSc in Textile Chemistry in 1980 and a doctorate in Physical Chemistry in 1985. Dr Hibbard carries out research in biophysical chemistry, particularly investigating the effects of near-UV radiation and high electrolyte concentration on ocular lens proteins. In addition to her work as a biophysical chemist, she has more recently been involved in chemical education research, focusing on the use of technology–enhanced blended or 'flipped' instruction, applied to her General and Physical Chemistry classes. Dr Hibbard currently serves as co-principal investigator on two NSF grants for these educational efforts. She has received numerous awards, including the QEM Excellence in Mathematics or Science Teaching Award and the Vulcan Materials Company Teaching Award, as well as the Spelman College Presidential Faculty Awards for Excellence in Teaching and for Distinguished Service. Dr Hibbard previously served as chair of the college's Chemistry Department and directed the Spelman Howard Hughes Program for several years. She is also a Fellow and past-president of the Georgia Academy of Science and a long-standing member of the American Chemical Society.

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FALLING IN LOVE WITH STATISTICS: SHAPING STUDENTS' RELATIONSHIPS WITH DATA

Statistical data analysis is a cornerstone of the sciences and operates as a shared language across disparate fields, from neuroscience to astronomy. However, current curricula often result in disengaged and stressed students who struggle to connect the concepts of statistics to the real world. **Professor Lisa Dierker** and her team at Wesleyan University have developed a novel approach to teaching statistics and data analysis that empowers students from diverse educational backgrounds. Her program, Passion-Driven Statistics, offers a multidisciplinary project-based approach that is both supportive and engaging for students at all levels of statistical mastery and those coming from diverse educational backgrounds.

Getting at the Data

Data analysis is a central component of science, technology, engineering and mathematics (STEM) fields, and is essential for scientific findings to be regarded as meaningful. In many ways, statistics can be viewed as the shared language of the sciences – the standard way for researchers and academics from disparate fields to converse with one another about data and evaluate each other's findings. A solid understanding of statistical methods and reporting is essential for communication between researchers both within and across disciplines.

Despite the necessity of statistics in many STEM fields, and an increasing demand for a statistics-literate workforce, traditional teaching methods often fall short. Many introductory statistics courses rely heavily on the memorisation of formulas and methods, often applied to abstract examples that lack the context students need to relate statistical methods to their lives or the world at large. It is common for students to regard introductory statistics courses as tedious at best, and overwhelming at worst. Given these challenges, it is unsurprising that students who are not required to take statistics courses seldom do, and students who choose majors that require statistics often take only the bare minimum requirements, rarely seeking out more advanced coursework once requirements are met.

Among students that do take an introductory statistics course, a firm grasp of critical concepts and how and when to apply them is not guaranteed. Due to the memorisation-based strategy adopted by many statistics teaching models, it is possible for students to learn formulas and definitions without ever using statistical methods to solve a real-world problem. At many universities, low-level statistics courses are taught in a large general lecture format within mathematics departments. As a result, the statistics that students are first exposed to can be completely divorced from the scientific disciplines and problems that the course is intended to prepare students for.

Further, without an understanding of how statistical methods are applied to real-world issues, students are unlikely to be able to use statistical understanding when evaluating data and figures presented to them in their everyday life. The common trope 'you can fudge the numbers to say anything', is really only true when the person reading the numbers does not understand how variables were measured and data were analysed. In a world where the average person is inundated with data on a daily basis, sorting out the signal from the noise is more critical than ever, and effective statistics education is essential to this skill.

‘This project is about empowering students to ask and answer questions that matter to them, while providing a skill set that can be a real game changer in the modern workforce.’

Diversity Drives Innovation

Humans have the distinctive ability to use communication to solve problems as a team. Often our most heralded advancements are the products of a diverse group of people collaborating with one another to work towards a greater goal. When people from dissimilar backgrounds collaborate, each is able to offer a unique perspective that builds upon and adds to the knowledge and skills of the team. However, forming diverse teams of scientists requires increasing diversity in STEM – an issue that has proven to be a stumbling block for educators over the past few decades.

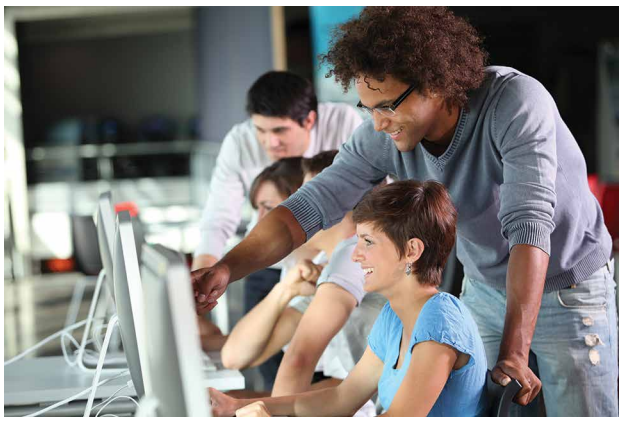
Students from disadvantaged backgrounds, minorities, and women are less likely to embark on STEM career paths, and those who do are more likely to change careers. Retention challenges range from lack of support, to lack of access to academic opportunities, to flat out discrimination. However, addressing these inequalities and retaining these students will benefit humanity at large. Solutions to the present challenges facing society will come from diverse teams of people working together for the common good – particularly in STEM fields.

After experiencing a rocky introduction to data analysis courses during her own education, Professor Lisa Dierker recognised the need for a foundational statistics course that is accessible to students of all interests and backgrounds. She has developed her Passion-Driven Statistics program to drive interest and understanding in learning statistics, while providing an environment that is welcoming and supportive of students from all backgrounds and skill levels. ‘Students don’t just need a seat in a classroom,’ she says, ‘they need a warm and welcoming place at the table. It is likely our greatest hope for creating a more equitable world.’

A Novel Approach to Teaching Statistics

In order to develop a more effective model for introducing youth to statistics, Professor Dierker realised she was going to need to abandon the traditional memorisation-based lecture method. She wanted to build a system that transforms students into self-motived young scientists, driven to learn about data analysis to satisfy their own curiosity about the world, rather than chase a grade or simply fulfil a requirement.

The perfect program would rise to many challenges: promoting multidisciplinary modes of inquiry that can be adapted across a wide range of problems, encouraging the flexible application of new knowledge, building new skills upon one another as new challenges arise, facilitating the use of modern computing tools, providing support for students at all skill levels, attracting and retaining students from underrepresented groups, and framing statistics as the basis for understanding complex information in the world at large. Professor Dierker and her team at Wesleyan University developed Passion-Driven Statistics to meet these lofty aims, by utilising cutting edge research into how humans are motivated to learn and best retain new information.



Passion-Driven Statistics aims to train students to approach problems with a statistical eye, so their skills are not simply memorised and then forgotten, but become a part of their intellectual toolkit and shape their perspective on the world. Rather than listen to lectures during class time and practice problems as homework, Passion-Driven Statistics flips the script: students work on projects of their own design in class, and complete readings and online lectures as homework. This means that students spend class time engaged in projects that pique their natural curiosity, learning the statistical methods necessary to answer questions specific to their interests. Rather than moving down a laundry list of required topics, students build on their statistical knowledge organically as they move through their project, forming more meaningful connections between concepts and methodologies. This gives students a sort of 'choose your own adventure' introduction to statistics, allowing them to learn data analysis tools that best address their research question and to make data management decisions that provide exposure to a wide range of statistical tools.

It is critical to Professor Dierker to ensure that the program is useful for all majors, and that students will be able to adapt their newfound statistics knowledge across the range of STEM fields to engage in interdisciplinary research. To accomplish this, students are taught terminology from across multiple fields. They are also given the option of working with data sets from a broad range of disciplines and must share their work with students from other fields, to further hone their interdisciplinary communication skills. To this end, students in Passion-Driven Statistics are given access to the same computational technologies commonly employed in many industries that collect and use data, providing exposure and experience with modern computing methods and statistical programs that they can expect to use in STEM careers. SAS, Inc., for example, an analytics industry leader, has been instrumental in supporting the program through their freely available, cloud-based platform, SAS Studio.

While a primary driver of Passion-Driven Statistics is the aim to imbue students with an appreciation for data analysis, it also aims to increase diversity in the sciences by fostering classroom settings that are inclusive and supportive. Traditional classroom settings place the burden of effort on the instructor – thus, class sizes must remain small in order for students to receive adequate support and direction. Many schools and universities lack the staffing to provide such instruction to a large student body, and must rely on the large general lecture. Professor Dierker's program leverages faculty, technology, and peer-to-peer learning to enable larger class sizes without losing individual support and attention.

While professors guide in-class activities, students also have access to online resource modules that are customised to their project and learning speed. Students also work together in groups, learning from one another and collaborating to fill knowledge gaps and building a motivating sense of community and comradery. Professor Dierker's team is working specifically to help tailor the program to attract and retain students from underrepresented groups, and is working to understand how innovative courses such as Passion-Driven Statistics can work to provide a foundation for freshman minority students to build their STEM careers upon.

Ultimately, Professor Dierker and her team want the program to shift the student view of statistics from a necessary evil to an essential way of understanding the world, and help students build confidence in their ability to analyse data. 'It gives young people who may never have seen themselves as "quantitative" or "technical" a chance to begin to see themselves differently,' she explains.

Driving Student Success

In its pilot at Wesleyan University, Passion-Driven Statistics has already begun to change the relationship that many students have with statistics. The course has been shown to attract higher rates of underrepresented students than a traditional statistics course, and student feedback from the course has been quite positive, with the majority reporting that it has been one of the most useful courses they have taken in college and that it has increased their interest in pursuing additional coursework in data analysis.

The model has been implemented successfully by numerous high schools, colleges, and universities, presently including Appalachian State University (USA), Ashesi University (Ghana), Concordia University (USA), Consortium for Pre-College Education in Greater Newark (USA), Davidson College (USA), GEAR UP partnerships at Yale University, Utah State University and Central Washington University (USA), Housatonic Community College (USA), Naugatuck Valley Community College (USA), Scarsdale High School (USA), Southwestern Oklahoma State University (USA), SUNY-Purchase College and SUNY-Downstate Medical Center (USA), Thiel College (USA), University of New Mexico (USA), Virginia Tech University (USA), and a TRIO partnership at Central Connecticut State University. In addition to these learning centres, the model has also been adapted to reach a worldwide audience as a Massive Open Online series of courses available through Coursera (for more information, see https://www.coursera.org/specializations/data-analysis).

With funding from the National Science Foundation and the Davis Educational Foundation, Professor Dierker is working to continue to build and refine Passion-Driven Statistics across additional learning environments and student demographics. Showing their commitment to inclusion, her team will be bringing their model to students with language-based learning disabilities in the coming year.

'After having demonstrated that this model is useful to students across many educational settings, we are currently working to identify additional implementation partners for a new grant application that focuses on national and international dissemination and sustainability of this project-based model,' says Professor Dierker. Those who are interested may reach her at ldierker@wesleyan.edu.

Meet the researcher

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Professor Lisa Dierker began her educational journey as an English major at Ohio State University, where she found herself drawn to the sciences, but intimidated by the heavy mathematical demands taught in unwelcoming lectures. She persisted and went on to earn both a Master of Arts and a Doctorate in Developmental Psychology at the University of Connecticut. After completing post-doctoral work in public health at Yale University, she joined the faculty at Wesleyan University, where she currently serves as a Professor in the Department of Psychology. Professor Dierker's early academic experiences inspired her to pioneer the Passion-Driven Statistics course – an innovative approach to teaching data analysis to students from a broad range of backgrounds and academic interests. Now in its ninth year, the course has met wide success and has been implemented in numerous schools worldwide.

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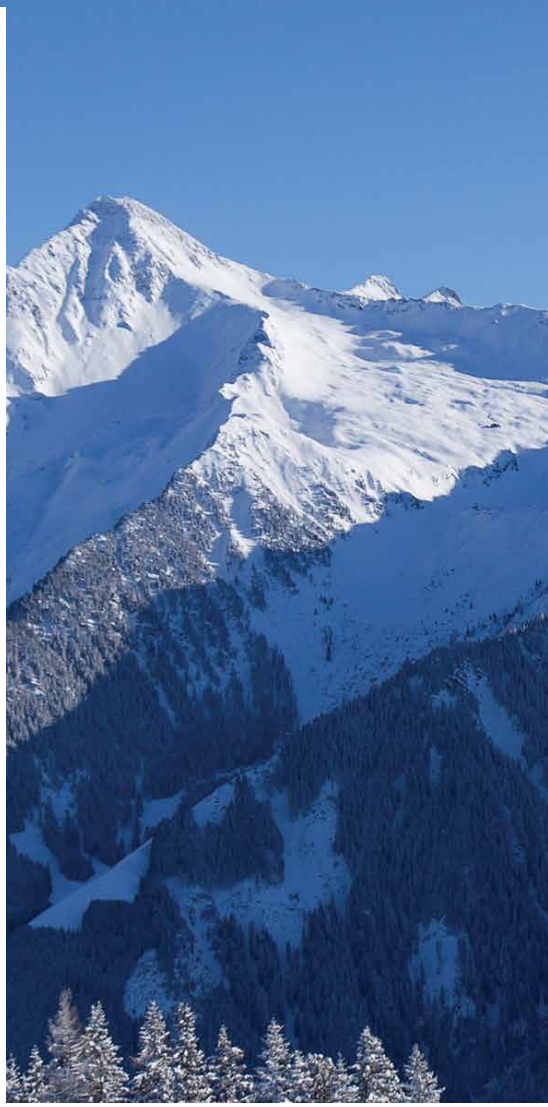
THE EUROPEAN FEDERATION OF GEOLOGISTS: SHAPING THE FUTURE OF GEOSCIENCE THROUGH OUTREACH AND EDUCATION



The European Federation of Geologists (EFG) is a non-governmental organisation representing over 50,000 geoscience professionals from 25 countries. Founded in 1981, EFG was established with the aim to work towards the safer and more sustainable use of the natural environment, promote the responsible exploitation of natural resources and protect the public from natural hazards. One of the ways the organisation achieves these goals is through their outreach and education efforts. In this exclusive interview, we have had the pleasure of speaking to EFG's president, Vítor Correia, who discusses the organisation's activities in increasing public awareness, and facilitating training and education in geoscience.

Please start by describing EFG's position on the importance of education and outreach in geological science.

I'd like to address this topic at two different levels.

The first is the importance of basic geological knowledge. Geology and the climate are the forces that shape the landscape and define where the resources we need for survival are. In this century, with climate change and a rising global population, the list of challenges that geoscience is needed to tackle is longer, and includes the capacity to counter soil erosion and maintain soil fertility, and ensuring the availability of water (both in terms of quantity and quality) for drinking and watering crops. This list also involves the exploration and exploitation of raw materials, the contribution to finding and using clean energy sources and the capacity to increase resilience against natural hazards (namely floods, landslides and droughts). Geoscience education at the elementary and secondary school levels should provide concepts that help young people (future citizens and policy makers) to understand natural systems, their constraints and the behaviours that we all need to adopt to live and survive in a planet under stress. However, as a recent survey from EFG's Panel of Experts on Education pointed out, geoscience education varies a lot in Europe (in terms of teaching time and subjects addressed).

The second level is about professional practice and competence. Geoscience encompasses a wide spectrum of different areas, including scales ranging from atoms to stars and time periods ranging from milliseconds to hundreds of millions of years. Because of this, it's virtually impossible to have a specialist whose expertise covers the many different topics where geological knowledge and societal needs meet. This is why EFG recognises competent geologists in 14 different areas (e.g. CO2 storage, minerals, geothermal energy), thus ensuring that these professionals have the necessary academic qualifications, combined with adequate professional experience and a superior track record. To keep up-to-date, competent geologists (holders of the professional title EurGeol) are required to present their annual Continuing Professional Development records to EFG. In this framework, Continuing Professional Development ensures the systematic maintenance, improvement and broadening of knowledge and skills, and the development of personal qualities necessary for the execution of professional and technical duties throughout a practitioner's working life. This is why I linked education and outreach to professional practice and competence. In my opinion, training and

Geoscience education at the elementary and secondary school levels should provide concepts that help young people (future citizens and policy makers) to understand natural systems, their constraints and the behaviours that we all need to adopt to live and survive in a planet under stress.

education are essential to address the pace of technological change in the geosciences, as well as the danger of skills' obsolescence.

Tell us a bit about EFG's EuroWorkshops programme, and how it will help to create a community of well-trained geologists that collaborate across national boundaries.

This is a fairly new programme. As I said, EFG requires annual records of Continuing Professional Development from its registered professionals. However, we realised that some professionals have limited training options, either because the offer is scarce in some specialities and countries, or because the costs of education and training courses are prohibitive. The EuroWorkshop programme was created to tackle this challenge. On top of that, because of our panEuropean coverage (the EFG includes members from 26 countries, from the Atlantic to the Urals), we realised that we had excellent conditions to offer the practical component of training in locations with clear linkages to specific geoscience topics. For instance, we can offer field training on porphyry copper deposits (common in South America and Asia, but less common in Europe) in Serbia or Bulgaria. If the subject is earthquake protection, we can learn from the Italian experience. If it is tunnelling and engineering geology, Switzerland has outstanding options. If it is mine rehabilitation, Germany and Portugal have best practice examples.
As you mentioned, we also decided that this programme should promote the exchange of experiences from different contexts and generations. For this reason, we reserve 50% of the seats to attendants from outside the hosting country and we provide financial support to young professionals and students participating in the EuroWorkshops, fostering collaboration across European geosciences professionals.

We just tested the concept in the organisation of our first EuroWorkshop in May. It was held in Greece and the topic was geothermal energy. We followed a two-day training model (an indoor workshop on the first day, followed by a full-day field trip on the second), and the results, measured in terms of the number of participants and their satisfaction, were above our expectations. We have already received suggestions for 11 EuroWorkshops, to be held all over Europe, with the support of EFG's National Associations, and the challenge we face now is to increase the periodicity of the EuroWorkshops. At the start, we believed that organising one or two EuroWorkshops per year would be enough to cover training needs of Geoscience professionals, but the inputs received demonstrated we need more.

The creation of the EuroWorkshops was definitely a good idea that will be expanded soon.

What is EFG's training course endorsement programme? How does it benefit the teaching and training of future geologists?

This is another mechanism we use to support training and dissemination of knowledge to professional geologists. The EFG endorsement works like a quality seal, which we offer to courses organised by EFG's National Associations. To apply for the endorsement, the National Association provides the course plan to EFG, along with the CVs of the trainers and generic information on the course structure, schedule and duration. This is analysed by a Council, and if the course meets our quality requirements, the endorsement is made, and EFG disseminates the training program to its audience of nearly 50,000 geologists in Europe. The advantage we get in return is transferred to the EurGeols, who benefit from reduced fees in training courses that are endorsed by EFG.

This initiative and its development was lead by the Coordinator of our Panel of Experts on Education (EFG has 10 Panels of Experts, who provide high quality advice and information to society and policy makers). The Panel of Experts on Education has been active in developing a qualification framework for geology based on learning outcomes, thereby increasing the transparency of Earth Sciences qualifications and ultimately facilitating academic and professional mobility across Europe. Considering this background, one can say that EFG's endorsement programme is a modest contribution towards the recognition of qualifications and enhanced professional mobility in Europe.

Perhaps the biggest challenge of our time is the threat of anthropogenic climate change. Does EFG encourage young people to pursue careers in helping to mitigate the effects of climate change, in areas such as geothermal energy or geoengineering?

I agree that climate change is probably the biggest challenge mankind is facing. To deal with it we will need integrated solutions, using inputs from different sciences. This is happening already in some areas, such as in the design of nature-based solutions to counter floods. In this case, inputs from physics, biology and geosciences, combined with insight from social sciences and engineering are being used to prevent loss of human life, damage to property and destruction of infrastructure as a consequence of floods.

However, I have the impression that the majority of universities are not prepared to change the way geoscience is being taught. We still see the classical separation between science fields and disciplines, with little integration between them. And note that this is happening at the dawn of artificial intelligence, which will use algorithms and huge amounts of data. In my opinion, and I recognise this might be polemic, if the geosciences want to offer positive and relevant contributions to help us cope with climate change, we should start teaching geoscience students more coding, statistics and data mining, and facilitating horizontal integration with other sciences (including social sciences) fields.

We normally don't address young people or students directly. However, many of our members work and teach at universities, and I know they are aware of this predicament.

I'd like to thank you for this opportunity to explain why we believe that geoscience education is critical to help the new generations dealing with future major challenges, and why EFG is keen in promoting the competence of geoscience practitioners.

www.eurogeologists.eu

HARNESSING MOBILE TECHNOLOGY TO IMPROVE STUDENT RETENTION

Dr Lori Silverman, an expert in education and student retention, is the Co-Founder and Chief Executive Officer of Colytix. The company, founded in 2016, is developing innovative tools for higher education students to improve success and retention rates in class, while creating a platform for the analysis of factors that contribute to student success rates.

Student Dropout in Community Colleges

Community colleges in the United States are public institutions that primarily offer two-year lower-level education degrees (AA, AS, AA-T, and AS-T) that focus on allowing students to transfer subsequently to traditional four-year universities. Besides associate degrees, they also offer technical degrees and certificates, in addition to providing remedial education and a limited number of bachelor's degrees.

Over 6 million students enrolled in community colleges in 2015, making it a popular choice among students. Data from the Education Longitudinal Study (2002-2006) showed that 44% students from low-income backgrounds preferentially attended community colleges as their first college after high school, compared to 15% of students from high-income backgrounds. This highlights the importance of community colleges in promoting a less expensive alternative route to higher education.

Furthermore, among all college students who enrolled in 2010 for the first time, 48.5% of Black students and 50.8% of Hispanic students started at a two-year public college, compared to 35.6% of White students and 37.8% of Asian students. More interestingly, for those college students who obtained a degree at a four-year institution in 2015-16, 49% had enrolled at a two-year institution in the previous 10 years.

However, one of the major issues facing community colleges is the high dropout rate of students – while students enrolled at four-year institutions are retained at a high level of 80–90%, only 60% of students in community colleges are retained from one year to the next. More importantly, although several programs are in place to increase student retention in these institutes, recent analysis shows there has been no real change in student retention rates over a period of eight years even though colleges spend almost 10% of their annual budget on improving retention rates. This suggests that the current strategies are ineffective.

Understanding the Root Cause of Student Dropout Rates

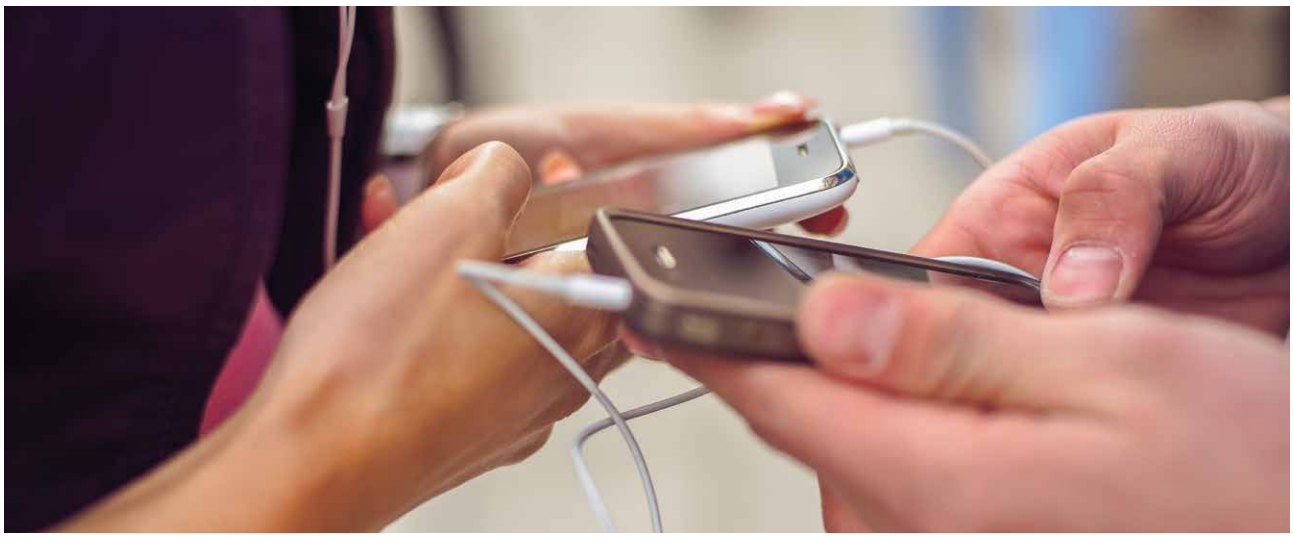
A study sponsored by the Bill and Melinda Gates foundation in 2011 shed some light on the reasons for low student retention in community colleges. Interestingly, none of the factors were related to the student's intellectual capacity, with 'non-cognitive' factors, instead, playing a major role in student dropout.

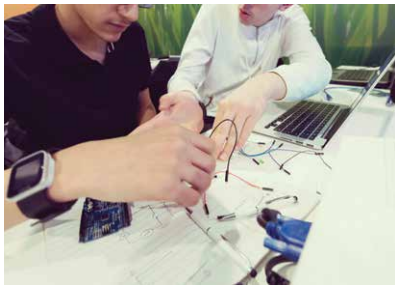
These factors included poor time management skills – relating to the students' ability to effectively manage study-related activities – lack of belief that the degree is valuable or attainable by the student and a lack of support for the student in receiving positive feedback for their accomplishments.

Dr Lori Silverman, an expert in education and student retention, is the Chief Executive Officer for Colytix, a company founded to develop tools for higher education students to improve success and retention rates in class. Colytix also provides a platform for data collection on the non-cognitive factors that contribute to student success rates.

Through her research and expertise in the field, Dr Silverman has previously observed that non-cognitive factors greatly influence the success of students and subsequent student retention and performance. However,

‘By developing more tools for assessing and improving the non-cognitive status of students as well as facilitating each students’ ability to better understand and adapt to their own learning, we are moving towards a college system with decreased dropouts and increased student performance.’





traditional approaches to improve student retention still focus on cognitive factors such as grades and standardised test scores.

Deploying an Idea to the College Community

Dr Silverman and colleagues have spent several years focusing on improving student retention in community colleges by addressing these non-cognitive factors. Colytix was founded in order to fulfil these unmet needs, by harnessing a powerful multi-million-dollar tool available on campus that was not being used to its full potential – mobile smartphones.

Drs Lori and Josh Silverman, co-founders of Colytix, realised that students were willing to engage with apps on their phone in a personalised way, and that they provided more information on social media than they would to a college administrator. This led them to the idea that a mobile app would help students engage with their teachers and with each other in a more productive manner.

Over 85% of community college students own and use a smart phone, giving Colytix a platform through which they could deploy their technology. Accordingly, the company has spearheaded the development of several apps and web-based technologies that are used to engage with students in a meaningful way to provide benefit to both the students and the teachers.

The company takes advantage of Dr Lori Silverman’s extensive research that helped identify key deficiencies in the current strategies of improving student retention. The vision of Colytix is to use this expertise to leverage technology in new and innovative ways in order to create new avenues of interaction between students, teachers and administrators.

Building a Strong Foundation

Dr Silverman has authored and coordinated several grants awarded by the National Science Foundation (NSF) that established her name as a pioneer in the field of student education and retention. The first of these, named STEMWay, was a five-year grant worth almost $1,000,000 that mainly intended to increase completion in college mathematics, with an associated degree or transfer to a four-year baccalaureate program in Science, Technology, Engineering or Mathematics (STEM) at Foothill College, Los Altos, California.

As part of this project, Dr Silverman led the integration of classroom instructions and student services by introducing the idea of having a supplementary instructor for STEM and by having a dedicated STEM counsellor on-site. She also initiated an early alert system for students who were in danger of failing their course, in which students could reach out to an early alert coordinator for available resources.

These measures ensured that the students always had resources available to discuss any concerns about their course and ensured their continual interest and education. By overseeing the creation of new courses, workshops and materials for STEM students and by developing areas related to research and data collection, project planning and non-cognitive interventions, Dr Silverman fostered an environment conducive to high academic success.

Overall, at the end of the grant, the result was an increase in the use of the dedicated STEM centre, which resulted in higher success rates in students and improved performance especially in mathematics

courses. Moreover, these interventions created a sense of community and belonging among STEM students and faculty and encouraged other faculty to apply for other similar government grants.

Another NSF grant on which Dr Silverman is co-principal investigator is the S-STEM grant. This $600,000 award was granted in 2013 for five years to provide financial and academic support to students who are considered 'at-risk' of dropping out. Executed together with STEMWay, this grant saw increased retention of scholars funded through S-STEM and improvement in student grades. 83% of S-STEM scholars also transferred to four-year institutions, representing a great success over the 29% who transferred without this support.

Continued Investment for Improved Retention

The success of Dr Silverman in executing the STEMWay and S-STEM NSF grants led to additional funding. The latest project is a Small Business Innovation Research (SBIR) proposal that involves the Assessment in Real Time of Individual Student Training (ARTIST) – a mobile app platform developed to improve student goal setting and engagement.

This $200,000 grant, awarded in 2017 for 12-months, aims to build and develop the ARTIST app to allow for continuous, real-time assessment of student learning and classroom engagement. The app is already available on the Apple store and Android store, with multiple classes and colleges already engaging with the app regularly.

The ARTIST app leverages user experiences from a previous app developed by Colytix that is tailored to individual learning styles to allow efficient learning at a student's convenience. Since students interact with the app throughout the class term, this allows for data on non-cognitive data factors to be gathered and assessed, giving real-time information on a student's engagement and retention risk.

The ARTIST app lets students take control of their own schedule and learning. The ultimate goal of the team is to develop a 'fitbit for education' – an individualised platform that breaks each student's long-term goals down into manageable, short term, individualised targets, while providing a community of other students and faculty to monitor progress, provide encouragement, and provide timely and appropriate interventions when necessary. By implementing these features, the app helps students succeed in class and complete their goals such as a degree completion, which is a direct benefit to both schools and students.

Setting Goals for the Future

The team has more ideas in the pipeline – the next tool is a mobile-app called 'Lasso' that is based on geolocation features, which they hope will create a new mode of communication between students and teachers. By advertising their location and their availability for group-study/tutoring, both students and teachers will be able to conduct spontaneous meetings and study sessions.

The team hopes that these kinds of interventions can help overcome the 'clique' mentality that develops in college students and will promote a more open and accessible group-study and learning system that will lead to higher student retention. The team looks forward to a future where mobile apps will be routinely used to assess student performance and the non-cognitive factors that are crucial for predicting student retention.

Dr Silverman says of their work: 'by developing more tools for assessing and improving the non-cognitive status of students as well as facilitating each student's ability to better understand and adapt to their own learning, we are moving towards a college system with decreased dropouts and increased student performance. Eventually, we want to create an environment where students can feel confident to take control of their own learning.'

Meet the researcher

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Dr Lori Silverman obtained a PhD in Education from Walden University in 2010 and an MS in Mathematics from San Jose State University in 2000. She has worked in higher education for over 18 years, during which time she has received three grants from the National Science Foundation (NSF) for improving student success in Science, Technology, Engineering and Mathematics (STEM). She is Founder, Chief Executive Officer at Colytix, a company focused on improving retention in community college students. She was associated with Foothill College in Los Altos Hills, California for several years where she served as a tenured member of the mathematics faculty, interim dean of the Physical Science, Mathematics, and Engineering Division, and currently serves as the Director of the Science Learning Institute. Dr Silverman is dedicated to closing achievement gaps and increasing diversity in STEM through application of new technology and innovations.

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TRANSFORMING BIG DATA INTO MEANINGFUL INSIGHTS: INTRODUCING QUANTITATIVE ETHNOGRAPHY

In the information age, humans produce data at an extraordinary rate, offering social scientists an opportunity to study our behaviour in a manner unprecedented in human history. In his new book *Quantitative Ethnography*, learning scientist **Professor David Williamson Shaffer** at the University of Wisconsin-Madison describes a novel theory and set of techniques for merging quantitative and qualitative analyses to discover meaningful patterns in big data.

Data in the Information Age

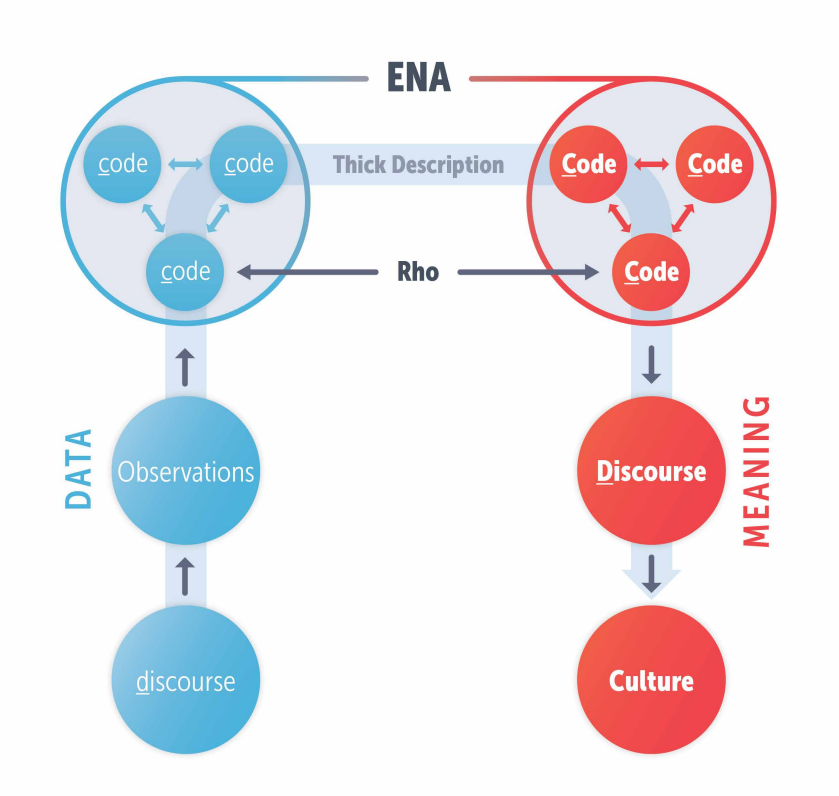
The internet and mobile computing have led to the largest shift in human record keeping since the advent of printed text. One hundred years ago, the first popular use cameras were just beginning to make their way into the average American family's home. Today, nearly 4.5 billion people carry mobile phones. Nearly a third of the world's population now carries a camera at all times and takes at least one digital photo every day. The average internet-connected person produces a gigabyte of data daily, close to two thousand books worth of information.

Data that would once have taken multiple lifetimes to compile is collected almost without effort as we communicate via email and text, entertain ourselves with online games, consume information on websites and engage with social media platforms. Many of us are not even aware of most of the digital records we create, such as credit card transactions, GPS pings from phones and vehicles as we move around and security camera footage. Every two days, we collectively generate as much information as was recorded in all of human history prior to the emergence of the internet – and this rate doubles approximately every two years.

Yet despite sensational news stories about the power of big data – the retail giant Target, for example, famously predicted which customers were pregnant by their shopping habits – making sense of the enormous volume of data collected is increasingly difficult. While computers can find patterns in big data, they cannot distinguish meaningful patterns from the random associations common in any sufficiently large dataset. And as the amount of data produced grows ever larger, the volume of meaningless patterns gets larger as well.

Our digital universe is, quite literally, growing at an exponential rate, and scientists are struggling to adapt classic methods of analysis to make sense of this bounty of digital data. Classical statistical techniques were not designed to handle massive quantities of data, and no human could read, let alone analyse qualitatively, even a fraction of most large datasets.

Over the last two decades, data mining techniques have emerged that use computer algorithms to identify patterns in human behavioural data, but they seldom provide meaningful context for the patterns they find. To see the problem, imagine a computer program examining the behaviour of chess players. The program will easily identify that advanced players typically move much more quickly than beginners. However, this pattern tells us nothing useful about how to play chess



well. Indeed, the very worst advice you could give to a new chess player is, 'Just move your pieces faster!'

Professor David Williamson Shaffer at the University of Wisconsin-Madison has built his career studying how we learn and process information. He was disappointed that even though we have more and more data about what learners do in classes and online, the limitations of existing big data methods do not do a good job of providing meaningful insights that shed light on the processes of learning and improve student outcomes. To address this problem, he developed quantitative ethnography, a novel approach to big data that combines quantitative and qualitative methods to make sense of complex phenomena in big data.

A Marriage of Methodologies

While both quantitative and qualitative methods benefit from collecting large amounts of data, they are difficult to merge because they have fundamentally different goals and strengths. Quantitative analysis is most powerful when it uses data about a large number of individuals to support general claims about a population.

Qualitative analysis is strongest when it uses a large amount of data about a small number of individuals to generate deep and meaningful insights about a small set of cases. Where quantitative findings tend to be shallow but broadly applicable, qualitative findings tend to be detailed but narrowly focused. Both are essential to a complete understanding of human behaviour, but combining them has historically proven difficult.

The rise of big data fundamentally changes this landscape. We can easily collect a large amount of data about large numbers of individuals, and the question is, how do we use that data to generate meaningful insights.

In recent years, many social scientists have championed mixed methods strategies involving both approaches. However, this typically involves quantitative and qualitative studies run in parallel or in sequence, with the hope that the results from one will inform the other. While the final results include both methods, the methods themselves are often employed separately. With quantitative ethnography, Professor Shaffer instead offers researchers a strategy to harness the power of big data to truly merge quantitative and qualitative approaches.

To appreciate the significance of quantitative ethnography, it is important to first understand the basic principles of quantitative and qualitative methods.

Quantitative methods employ statistical analysis so that researchers may acquire data from a subset of the population and use it describe a general feature of the full population. It relies on scientists obtaining a representative sample with similar characteristics to the larger population they hope to describe.

The advantage of quantitative approaches is that they provide support for claims that something observed in a sample is generalisable to the population from which the sample was taken. Statistical techniques do this by distinguishing between 'true' characteristics of the population and the normal random variations among the individuals within it. This often requires relatively large samples, which helps to ensure that the random variations cancel out and the systematic effects – the true characteristics – can be identified.

Ethnography, on the other hand, is a qualitative field that aims to describe and understand the structures of societies and cultures. In contrast to the large, impersonal sample sizes of quantitative analysis, ethnographic methods rely on in-depth observations of small groups of people, with the goal of creating 'thick' descriptions of *why this particular group of people* do the things they do.

Ethnographers gather information to create a portrait of people's lived experiences that puts their activities in context and lets researchers make sense of their behaviour. The object is to identify the connecting causes between behaviours that explain how and why something happens a particular way in a particular context, not to make claims about the broader population. To make sure their analyses are sufficiently robust, or 'thick', qualitative researchers continue collecting data until they reach theoretical saturation, a point at which new observations act to confirm existing hypotheses rather than providing additional insights.

Successfully merging these two approaches requires a method for providing 'thick' descriptions of a large population, using both the general claims of quantitative methods and the deep insights of qualitative methods.

Finding Meaning in Chaos

Professor Shaffer argues that big data provides a unique opportunity for advancing

social sciences that we have only begun to explore. In his own field of education, more data about learning is now available than ever before – data from large-scale online courses, educational games and simulations, computer-based tests, and other digital learning programs and tools. Big data offers a unique set of both the massive numbers of individual participants required for statistical analysis, and the incredible depth of information about each one that allows for qualitative analysis.

Professor Shaffer's new book, *Quantitative Ethnography*, shows that the incredible amount of data available makes it possible to incorporate qualitative and quantitative analysis within the same conceptual framework. *Quantitative Ethnography* begins with the idea that learning is a process of becoming part of a culture, and that the manifestation of a culture is a *Discourse*, the patterns of communication and interactions characteristic of that culture.

However, *Discourse* (with a big D) is not observable. What can be observed is *discourse* (with a little d), the actual things that people say and do and the many ways that they act and interact. To understand a culture of learning, researchers need to find a way to go from *discourse* to *Discourse*. To take the specific things that students said and did and work out their meanings.

A key part of that process is coding. *Codes* (with a big C) provide a system for interpreting parts of a *Discourse*, or for understanding what things mean within a culture. Creating a culture (Enculturation) therefore requires learning the right *Codes*. For example, when archaeologists analyse soil, they describe its characteristics – things like colour and texture – in consistent terms that any other archaeologist will easily understand. To make their descriptions consistent, archaeologists use tools like a Munsell Colour Chart to measure and describe soil.

Things like a Munsell Colour Chart and the texture of soil are *Codes* in the archaeologists' culture that are different from the *Codes* that farmers would use to describe the same patch of ground. For one thing, most farmers do not use a Munsell Colour Chart. Both the culture of archaeologists and the culture of farmers have consistent *Codes* for describing soil, because soil is important to each culture.

The study of learning means identifying the *Codes* within patterns of *discourse*, and placing them into the context of the culture being studied. But as with big D *Discourse*, big C *Codes* are not directly observable. Researchers need to identify *codes* (with a little c). The things people say or do that provide evidence for the *Codes* they are using.

Critically, however, simply *identifying* the *Codes* in a *Discourse* does not provide a 'thick' description of a culture. To understand why people, act the way we do, we also need to understand how the *Codes* are related to one another.

For example, a Munsell Colour Chart is meaningful to an archaeologist because it is a way to systematically record the colour of soil – as well as a whole set of practices about how to select, grade, and record soil samples. In this sense, soil and Munsell Colour Charts and other *Codes* from the *Discourse* of archaeology are related to one another. And learning to become an archaeologist, in turn, means learning these *Codes*, and learning how they are related to one another.

Professor Shaffer and his team have also developed a set of tools and techniques for quantitative ethnography – a set of methods for merging statistical and ethnographic analyses. This toolkit includes an advanced statistical tool called Epistemic Network Analysis, or ENA, a network analysis tool used to model how *Codes* are related to one another in a set of data. ENA models visualise a system of connected *Codes*, and let researchers use statistical methods to quantify and test the differences between them. Tools like ENA let researchers test whether a description of a group of people is theoretically saturated.

In the context of learning research, quantitative ethnography provides an approach that allows researchers to identify meaningful differences in enculturation among different groups of learners. Classical statistical methods allow researchers to determine whether learning tools are effective for students, but quantitative ethnography allows researchers to discover *why* – and to show teachers and parents and other educators how their own students are thinking about a subject and what connections between ideas the students still need to make.

Professor Shaffer's methods add a new layer of understanding that takes researchers beyond just describing whether a curriculum or online learning system works, and into a realm where they can identify critical components of learning that shape the success of a program.

The Future of Big Data & Learning

Technological advances over the past two decades have revolutionised how we as human beings consume and produce data. These changes challenge researchers to find new ways to meaningfully analyse the enormous amount of data that is now available.

Professor Shaffer's quantitative ethnography gives scientists the analytical tools to both describe learning and understand how and why learning occurs. By merging tools for testing statistical significance with techniques to generate deep understanding, the methods described in *Quantitative Ethnography* allow researchers to illuminate new paths forward in teaching, learning and in understanding the how and why of human behaviour.

Meet the researcher

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Professor David Williamson Shaffer is an internationally recognised expert on teaching and assessing modern skills through educational games. He is best known for his work using quantitative ethnography to measure complex thinking, and for the development of Virtual Internships that teach and assess students in high school, college and corporate training. Professor Shaffer completed his M.S. and Ph.D. at the Media Laboratory at the Massachusetts Institute of Technology, and has taught in the Technology and Education Program at the Harvard Graduate School of Education. He is currently the Vilas Distinguished Professor of Learning Sciences at the University of Wisconsin-Madison, the Obel Foundation Professor of Learning Analytics at Aalborg University in Copenhagen, and a Data Philosopher at the Wisconsin Center for Education Research. Professor Shaffer served in the United States Peace Corps and was a 2008-2009 European Union Marie Curie Fellow. He is the author of *How Computer Games Help Children Learn* and his most recent book is *Quantitative Ethnography*, an introduction to the new science of studying the human side of big data.

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REFERENCES

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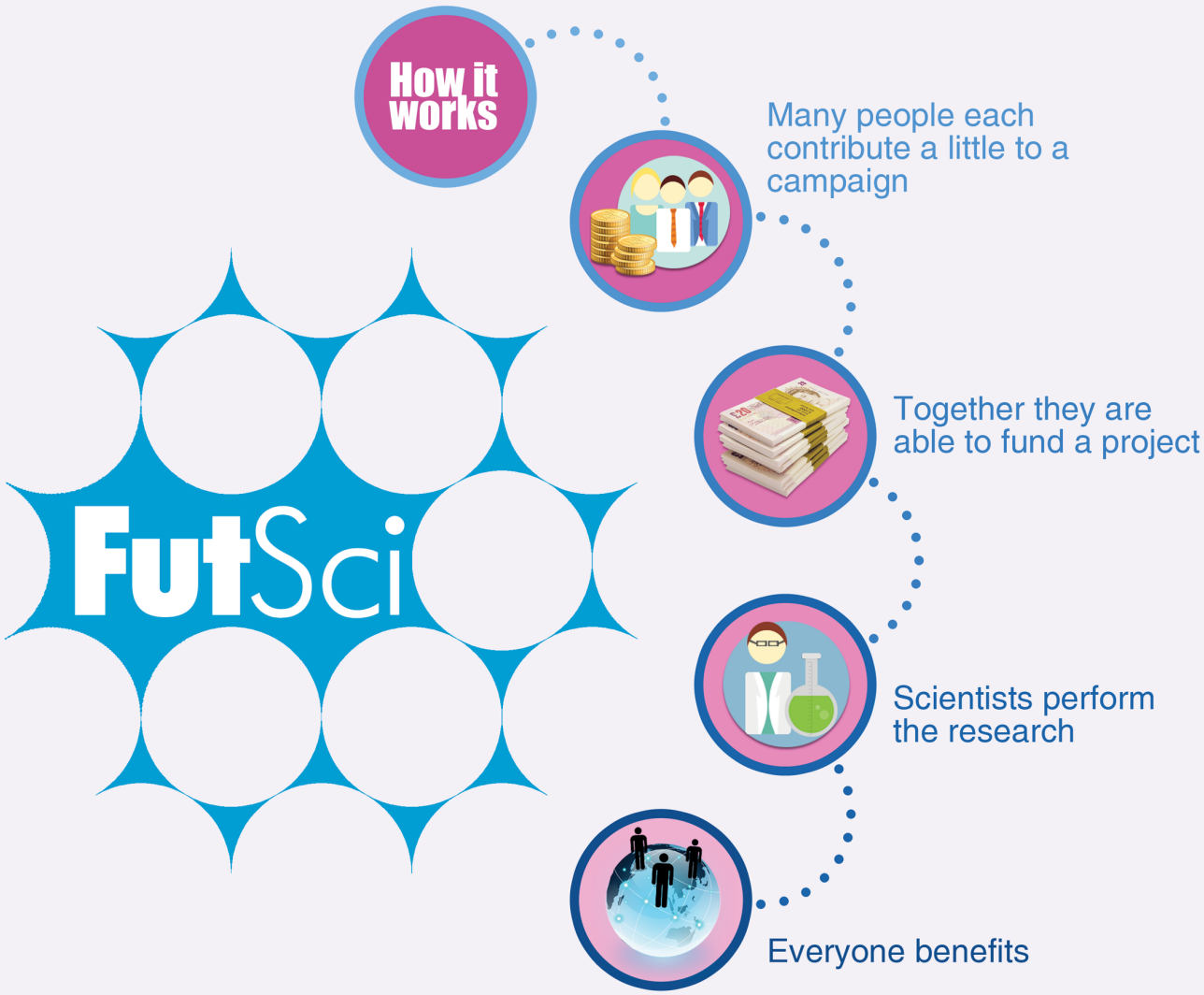

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