

Foundations of science

An expert in teacher professional development, **Professor Tanya Furman** is working with collaborators to forge innovative approaches to communicate Earth and space science to middle-grade students



Could you introduce the Targeted Math Science Partnership project?

The system-focused nature of Earth and space science (ESS) promotes the integration of mathematical, physical and biological sciences to address real-world topics. Despite its clear and increasing importance, these subjects are often short-changed or bypassed in school curricula. One reason for this is that we face a national dearth of certified ESS teachers in secondary grades. When teachers themselves lack deep understanding, then ESS (like any other subject) is taught in ways that encourage the memorisation of vocabulary rather than the conceptualisation of processes and phenomena. The Partnership brings together university faculty members and graduate students with public school teachers who focus on ESS topics in their classrooms in order to improve the teachers' command of the content material, and promote effective instructional approaches that will allow students to achieve a rich understanding in these key areas.

Why did you decide to focus on middle-grade ESS education?

Our work targets middle-grade ESS students and their teachers for several reasons. First,

ESS is the gateway for students' participation in STEM fields in high school and beyond. It is typically taught in the key middle grades when students – women and minorities in particular – face stereotype threats that influence their career and educational choices. Second, middle grade ESS teachers are often teaching outside of their expertise and certification. Third, ESS is the field most easily linked to students' own environs and life experiences, making it a universal vehicle to engage in authentic learning experiences. As America's leadership is focusing attention on ESS-related areas of energy production and climate change, it is critical to increase fundamental understanding of these topics. ESS is where students first encounter critical conceptual complexities regarding both scale and deep time. By improving students' mastery of ESS content, we will develop a citizenry poised to make informed decisions about future challenges.

Would you highlight the global ramifications of your project?

The ESS domain – and our work with teachers – focuses on several topics of global importance including energy use, natural resource management and climate change. In addition, we hope to achieve a broad improvement in STEM teaching and learning, as the skills of observation, data analysis, argumentation and integrative thinking are readily transferrable to other fields. Unique to ESS fields are the extremely large temporal and spatial scales that present conceptual challenges, which must be faced in order to understand planetary processes.

What strategies have you employed to accomplish your objectives?

Our primary strategy to improve the status, teaching and learning of ESS has been a suite of intensive professional development workshops for in-service teachers. We have offered week-long residential workshops focused on Solar System astronomy, plate

tectonics, climate and energy for the past four years, involving some 80 teachers from our partner districts. The workshops are truly collaborative between scientists and educators, as they focus on both content knowledge and instructional strategies, and specifically claim-evidence-reasoning and content storyline, which have proven effective in scaffolding student learning in the STEM fields.

In what ways will your programme enhance communication and collaboration in learning and teaching between colleges and campuses, underserved urban and rural school districts, and across the Partnership?

We have developed some robust relationships with teachers in several public school districts that will long outlive the project itself. Communication and collaboration are built on strong interpersonal relationships with individuals who share common struggles, experiences and values. Through our workshops, university personnel and in-service teachers have come together around the challenges of learning and teaching in the ESS domain.

How do you envisage the Partnership developing in the future?

We have reached the mid-stage of our project and are now working to identify and support legacies that will outlive us all. This represents a shift in focus from providing professional development and classroom examples to being able to stand on the sidelines and watch new professionals blossom on their own. We need to set up structures that will enable teachers to connect with one another (the Pennsylvania Earth Science Teachers Association, for example) and to provide professional development for one another. These are exciting times and we want to position Pennsylvania State University as a leader in improving STEM teaching at the college level.



Sharpening **intellects**

Educators in the US have embarked on an innovative project – the **Earth and Space Science Partnership** – aimed at improving the teaching, learning and status of middle-grades Earth and space sciences to boost students' capabilities in a field of increasing global importance

EARTH AND SPACE science (ESS) is an important part of the US school curriculum, and is usually taught from kindergarten through to the first year of high school. ESS covers a broad range of topics ranging from geology and oceanography to the Solar System. Interestingly, many of the major political challenges facing Americans today fall within the realm of ESS, including management of energy resources, tackling climate change and mitigating natural disasters. These issues emphasise just how fundamental understanding of ESS is to the long-term sustainability of the Earth and its inhabitants.

Despite the importance of ESS, there is a tendency for the discipline to be underrepresented in school curricula, at least in part because of the lack of well-prepared science teachers, especially in grades 4-9 (ie. 9-14 years), before American students start high school. Only 1.2 per cent of the thousands of students who took the SAT exam in the last two decades expressed interest in pursuing physical sciences of any kind. The associated low STEM course enrolments mean the US is now confronting a deficit of adequately trained ESS

teachers and professionals at a time when this study area is becoming increasingly important.

SUSTAINABLE COMMUNITY

At the University Park campus of Pennsylvania State University (PSU), researchers have embarked on an innovative science education and research project – the Targeted Math Science Partnership: Middle Grades Earth and Space Science. Funded by the National Science Foundation (NSF) and led by Principal Investigators Professor Tanya Furman and Associate Professor Scott McDonald, the Partnership aims to build a sustainable community of students and teachers who are academically equipped to tackle the grand challenges of the 21st Century. The group has a long-standing interest in teacher professional development in the field of ESS and a great deal of their work puts an emphasis on increasing the proportion of students from historically underrepresented groups in STEM disciplines.

The Partnership is a collaboration between academics in the disciplines of geosciences, astronomy and curriculum and instruction

(C&I) at PSU; teacher leaders from chronically underperforming urban and rural schools in Pennsylvania; and a team of external programme evaluators from WestEd. Furman believes that cross-disciplinary thinking is fundamental to both the study of ESS and to education in general, and this is reflected in the academic backgrounds of the personnel. Co-Principal Investigators of the project include Chris Palma (astronomy), Laura Guertin (Earth science) and Theresa Lewis-King, a veteran provider of teacher professional development and current eighth-grade teacher. Project Manager Susan Lauver brings budgetary and organisational skills to the mix, while external evaluator Susan Mundry helps to keep the participants focused on the project's long-term goals. The team is completed by Julia Plummer (C&I), head of the astronomy education research team, postdoctoral researcher Meredith Bembenic and webmaster Eric Aitala who ensures that all of the project's work remains accessible and in the public eye. "We have assembled a great team of individuals with key expertise in a wide range of areas. It is crucial that ESS professionals and educators work together to attract top students into our fields and challenge them in

ways that sharpen their intellects," explains Furman, whose own academic background is in geochemistry.

PROGRESSIVE LEARNING

ESSP is somewhat unusual in that it has both a research and service focus. The research is divided into two areas of student science learning: formation of the Solar System and plate tectonics. The project team completed conceptual interviews with students from grade four up to undergraduates in college on both topics. The responses have been analysed to allow the research team to develop hypothetical learning progressions, which are descriptions of how a student's understanding of science concepts develops over multiple years. Such progressions can help teachers identify key levels of student understanding, allowing educators to recognise potential obstacles in the learning process, and are used to help guide assessments, teaching and the development of new curricula in ESS. "Our hypothetical learning progressions in Solar System astronomy and plate tectonics are based on scores of interviews with students around these big ideas in science," explains McDonald. "We truly are creating new knowledge around how people learn in these critical domains."

Through working with teachers in this way, the ESSP team intends to improve ESS teaching in the classrooms from elementary school to college. The aim is to integrate the team's deep understanding of science, innovative practices of teaching and research into how students learn, in order to transform ESS in schools.

Impacting teaching is the second focus of the Partnership and involves teacher professional development. The group organises workshops for teachers, as well as courses for teachers-in-training, to improve their content knowledge, teaching practices and confidence as educators. "Our project has been developing a core of highly-skilled ESS teachers and helped elevate the morale and status of these hard working and talented professionals," McDonald enthuses.

Building personal and professional relationships with teachers will ultimately lead to a true K-16 continuum for students, or a continuous progression in ESS learning that covers the whole trajectory of a child's education, from primary school to college graduation.

SHARING STRATEGIES

Participants are already looking at ways to ensure their research remains useful even once the project has finished. To this end, the Pennsylvania Earth Science Teachers Association



THE TEAM EXPLORES THE NIGHT SKY

(PAESTA) was established by the team in 2011. PAESTA is committed to advancing and improving Earth science teaching and learning across the State of Pennsylvania. Networking through the Association allows educators to discuss successful strategies for sharing science content in a way that encourages students to engage with the often complex fields of ESS. "PAESTA will be a lasting legacy for teachers in Pennsylvania," outlines Furman. "More than 400 individuals rely upon this organisation for high-quality curricular and professional development materials and we are currently engaged in developing a funding stream to sustain this work into the future."

WISE DECISION MAKERS

Looking ahead, the researchers are involved in a synergistic effort with other academic colleagues who specialise in climate risk analysis and mathematics. This work will be central to the project's teacher professional development activities in summer 2014. Meanwhile, the Partnership will continue to impact the STEM curriculum in urban and rural schools across Pennsylvania, with a particularly marked focus on students from traditionally underserved segments of society. Providing teachers with the appropriate skills and encouraging young students to follow analytical thinking processes also has far broader implications; it will lead to future generations who are intellectually equipped to make major decisions about the Earth's future, whether in terms of energy use, management of natural resources or tackling climate change. In addition, the team is working with colleagues in mathematics to support professional development around implementation of the 'Common Core' standards, which present new challenges for teachers. As Furman concludes: "Without a global citizenry capable of understanding the complex and quantitative nature of ESS issues, we cannot make collective wise decisions for our planet, ourselves and generations to come."

INTELLIGENCE

TARGETED MATH SCIENCE PARTNERSHIP: MIDDLE GRADES EARTH AND SPACE SCIENCE EDUCATION

OBJECTIVES

The Partnership connects Penn State faculty members to middle-grades public school teachers to improve deep understanding of Earth and space science. The team employs professional development in scientific content and teacher leadership, and conducts research on student learning to prepare citizens to take on important scientific, energy and natural resource challenges.

PARTNERS

Pennsylvania State University

US School districts: Philadelphia; York; Reading; State College Area; Bellefonte Area; Bald Eagle Area

Evaluator: WestEd

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TANYA FURMAN graduated from Princeton University in 1982 with her Bachelor's degree in Civil and Geological Engineering. After a Fulbright fellowship year in Iceland, she carried out her doctoral research in geochemistry at MIT. She came to Pennsylvania State University in 1998 (to the Department of Geosciences) where she served as Undergraduate Program Head and as Associate Director for the Alliance for Education, Science, Engineering and Development in Africa.

SCOTT MCDONALD is Founder of the Invisible College for Inquiry Science Study (ICISS), a researcher-practitioner group of science educators focused broadly on the development of a theory of teaching for inquiry science pedagogy. His current work, funded by the Knowles Science Teaching Foundation Young Scholars Fellowship, examines professional pedagogical vision in prospective and practicing science teachers.

