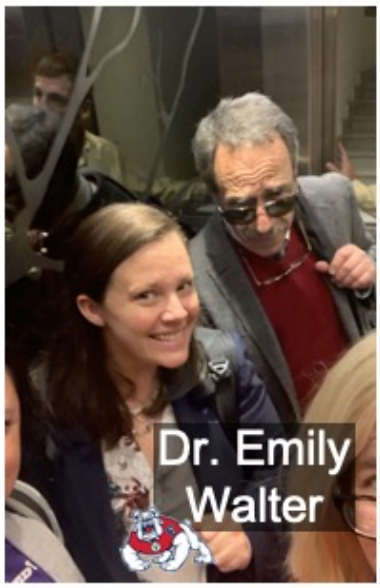
Hello. Today I want to tell you about some work that we have been doing, creating transdisciplinary curricula in Egypt. This work has shown us the power of integrating cross-cutting STEM concepts, disciplinary STEM content, and local phenomena and has illustrated both the benefits and challenges of a transdisciplinary approach to curriculum development.

Abstract (for reference only, not part of script):
Following the establishment of the first STEM school in Egypt (in 2011), the Egyptian Ministry of Education and the USAID-funded Egypt's STEM School Project began joint work creating a public STEM high school model, supported by US STEM education experts, that addresses 11 major Grand Challenges (GCs) identified by Egyptians. In 2018, the Egyptian Ministry of Higher Education and Scientific Research and US STEM faculty, coordinated by 21PSTEM, began creating 4-year undergraduate and 1-year post-Bachelor programs to prepare teachers for these schools, under the USAID-funded STEM Teacher Education and School Strengthening Activity (STESSA), also based on the GCs. Traditional Earth science alone was not sufficient to prepare students to meet these transdisciplinary GCs. Instead, the STEM high schools, as well as the graduate and undergraduate programs, use a transdisciplinary curriculum, with biology, chemistry, physics, Earth science, and math taught every semester. The content is further integrated every semester in capstone project experiences. These curricula were jointly developed by US and Egyptian STEM content experts who also did teacher training. These STEM schools have been a major success, catapulting Egyptian youth into wins at

international STEM competitions and earning them admission to elite universities around the world. As the schools developed, the Ministry of Education and 21PSTEM (which implements STESSA) found that US-Egyptian professional development helped ease teachers' transition to the integrated curriculum. But a growing number of STEM high schools made a new teacher pipeline imperative. US and Egyptian faculty are developing new 4-year undergraduate programs to prepare teachers in 5 STEM disciplines. These programs echo the high school curriculum and the GCs, but are more explicitly transdisciplinary, beginning with 6 integrated STEM courses in the first two years. Earth science plays a prominent role in these integrated courses and Earth science faculty from the US and Egypt have played a significant role in course development. We will report on the development and progress of the first two of these transdisciplinary courses, and the potential of truly transdisciplinary course work to develop stronger Earth scientists, ready to meet grand challenges in any nation on Earth.

Our Team



I am Dr. David Smith, a structural geologist by training, an independent STEM education consultant, and an artist, working in silicate lava. My co-authors are Dr. Emily Walter, a biologist at CSU Fresno, and a specialist in science education and science denial, and Dr. Fred Nelson, the Chair of Liberal Studies at CSU Fresno and a specialist in science education.

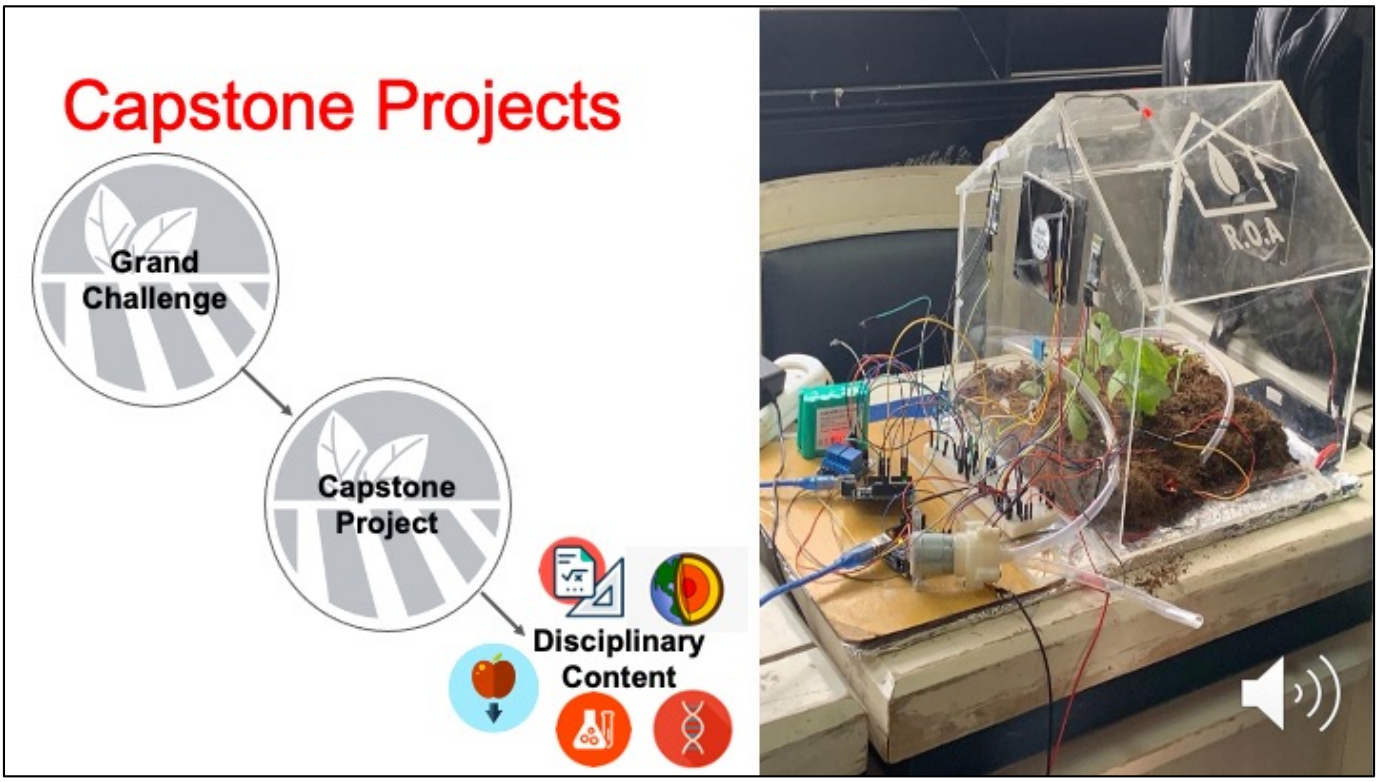
We are part of a large team of professors, consultants, and professional developers in STEM disciplines, STEM education, curriculum development, and assessment in both the US and Egypt who have been working together to build transdisciplinary STEM curricula and implement them in Egyptian high schools and universities. This project began as a contact between the Philadelphia-based 21st Century Partnership for STEM Education and a delegation of Egyptians visiting US STEM high schools near Philadelphia to look for models. It has since expanded to involve many more people and multiple institutions in both the US and Egypt.

The development of transdisciplinary STEM curricula in Egypt has been ongoing for nearly 10 years. This work has involved hundreds of people, both in the United States and Egypt and has been funded by the US Agency for International Development. One of our Egyptian colleagues uses this quote when he wants to impress upon people both the magnitude of the project and its importance to the people of Egypt.

The first project, the Egyptian STEM School Project began in 2012 with the first grant from USAID. In Egypt, USAID leadership came from Hala El Serefy and Reda Abouserie. This first project supported the creation of new public STEM high schools in Egypt. The project developed a new transdisciplinary stem curriculum for the STEM high schools, and began training teachers to teach STEM subjects in those schools. In this curriculum, every STEM subject is taught throughout each of the three years of high school (equivalent to grades 10-12 in US schools). This project enjoyed substantial political support in Egypt and was rapidly expanded from two initial STEM high schools, one in Cairo, and this one in 6 October City, to a total of 11 schools by the end of this first project in 2017. Today there are 19 STEM high schools and the ultimate goal is 27. These schools are public boarding schools, funded by the Egyptian government, with competitive admissions.

The Prime partner for this first project was World Learning in Egypt. The US partners were the 21st Century Partnership for STEM Education, a STEM education consulting firm, led by Joe Merlino, the Franklin Institute, a hands-on science center, whose participation was led by Dr. Frederick Bertley, and TIES, a STEM education consulting firm, led by Jan Morrison.

The Egyptian STEM school curriculum was developed directly from 11 Grand Challenges, identified by Egypt, and it is intended to engage students in meeting those challenges, beginning in high school and continuing on through the rest of their lives. As you can see, many of these challenges have important Earth system components and Earth Science is an integral part of the STEM school curriculum. Earth science, biology, chemistry, physics, and mathematics are all taught every semester in the STEM schools. It should also be clear that these Egyptian Grand Challenges include many issues that are grand challenges in many places in the world.



One of the most unique features of the STEM high schools is the presence of a Capstone project in every semester. Capstones are semester-long, stand-alone, group projects with increasing autonomy and responsibility placed on the students as they progress through the three years of high school. The projects involve engineering design, and it is common for students to create models or prototypes of potential solutions to problems found in Egypt. Many of the prototypes may include components developed in the Fab Lab that is present in each of the schools. These Capstone projects provide explicit transdisciplinary integration of the curriculum. And they drive the sequencing of the STEM content in the curriculum in a backwards design approach. In other words, it's not that the capstone was chosen to pull together the disciplinary content from the semester, but that the disciplinary content was chosen to support the capstone. For example, in the semester when students have to design a more sustainable dwelling, the Earth science course focuses on Earth materials and includes a specific unit on Egyptian building materials. This leads to a curriculum order that is significantly different from traditional curricula in either the US or Egypt, and a curriculum that is more easily integrated across disciplines.

STEM School Success

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Science, Technology, Innovation and Partnerships | May/June 201

These 3 Egyptian Girls Are Among the Smartest Teens in the World

Claudia Gilmore Gutierrez

Left to right: Mona El Sayet, Hoda Mamdouh and Sara Ezat. Last year, these students from the Maadi STEM School for Girls

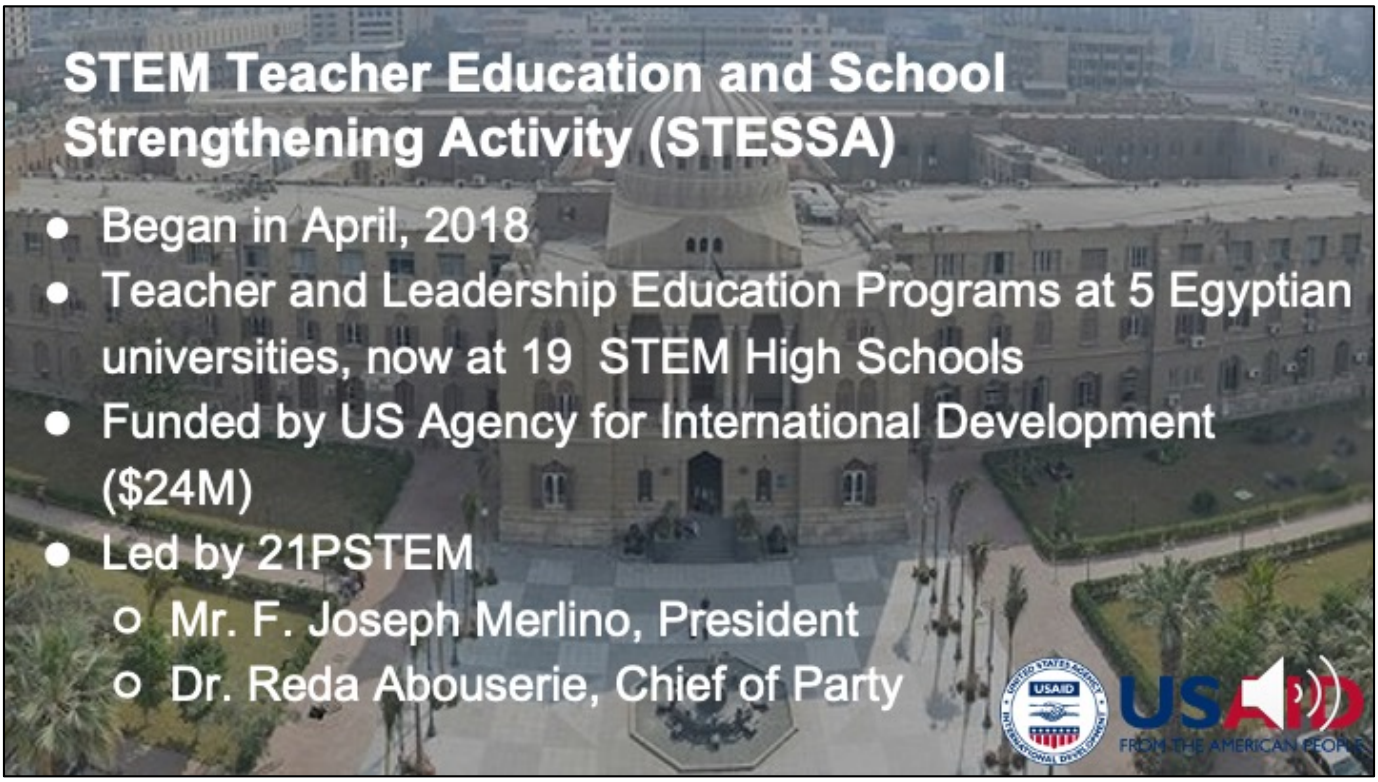
Even in the early years of the STEM school project, the impact of the new curriculum and instruction rapidly became apparent. These three young women took one of their Capstone project to International Science and Engineering Fair, and won. They became a sensation in Egypt and they are the epitome of what this work is about. Other student groups have followed them to significant international recognition and to admission to elite universities around the world.

Challenges Remained

Teachers and administrators:

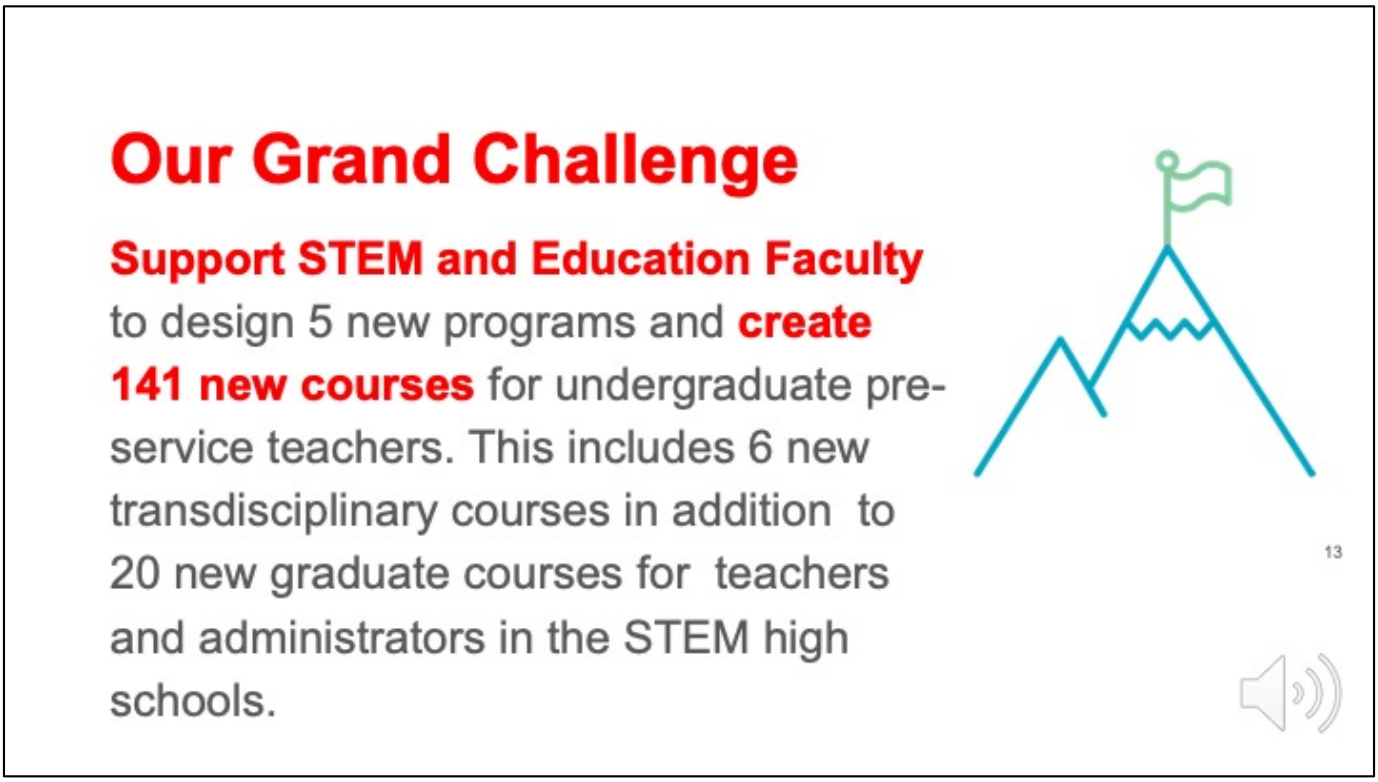
- graduated university unprepared to teach or lead in the unique STEM schools
- needed extensive additional training to be effective in STEM schools
- had high job turnover in STEM schools

The STEM schools also faced significant challenges. One of the greatest of these was staffing. STEM schools require teachers to demonstrate conceptual understanding of their disciplines and many teacher candidates were eliminated due to lack of this understanding. One root cause of this problem was the traditional lecture-based and memorization-focused instruction in Egyptian universities. Teachers and leaders who had not experienced either inquiry and active learning strategies themselves, especially not in STEM subjects, needed extensive training prior to assuming their positions. This training had to be squeezed into the summer between graduating and assuming their posts. As the number of schools grew, there was a dramatically expanding need for summer training. This need could not easily be accommodated by the trainers who had been working with a much smaller number of teachers during the start-up phase. In addition, lack of background and limited training meant that teachers and administrators sometimes struggled in their first years, which led to high teacher and leader turnover, further increasing the training burden.

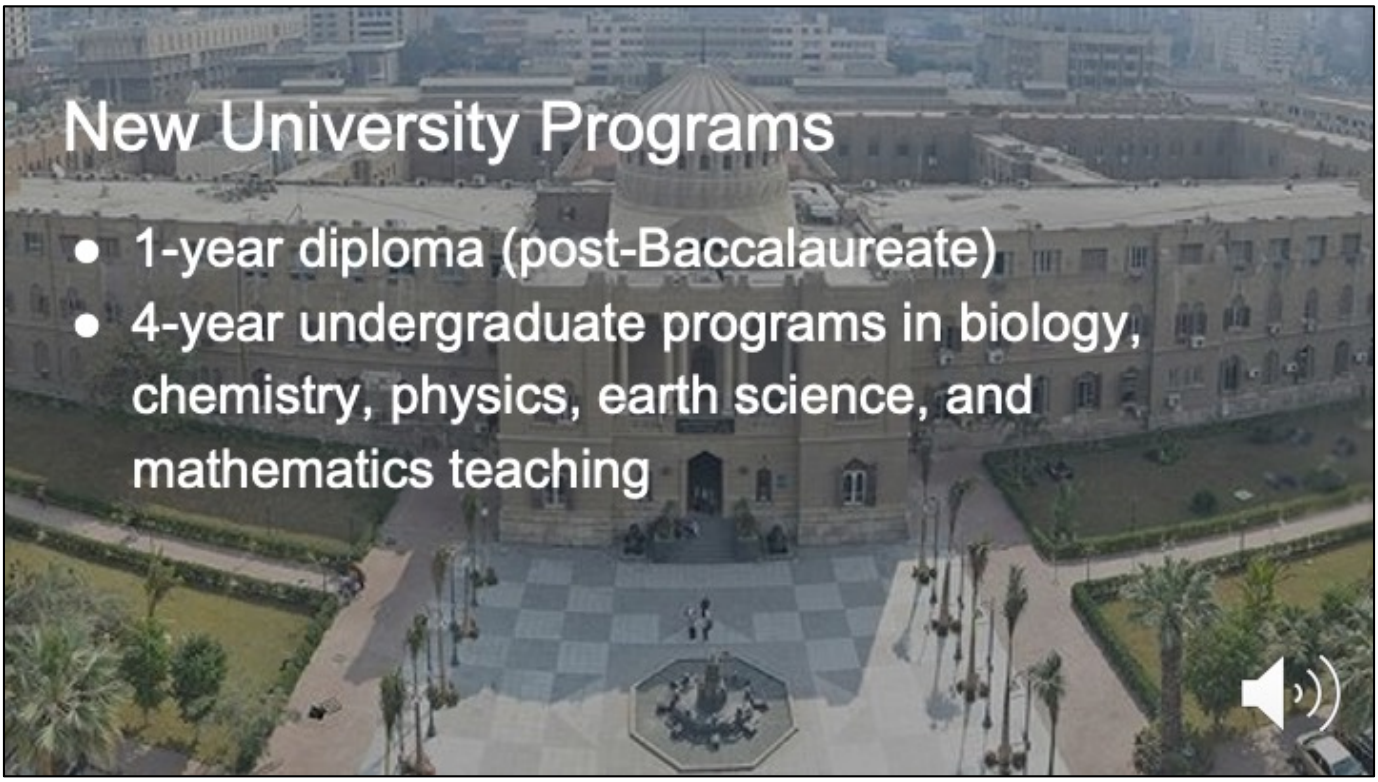


This need for an increasing supply of well-prepared STEM school teachers and administrators led to a new proposal and a new round of funding from USAID. The second round of funding supported the STEM Teacher Education and School Strengthening Activity, STESSA, a significant new partnership between Egyptian and American universities, coordinated by 21PSTEM, in order to develop new teacher preparation programs, specifically to meet the needs of the STEM schools. By this time, in 2018, 21PSTEM had established a field office in Cairo, led by Dr. Reda Abouserie. In this new project, which is in its third year, Egyptian and American faculty and consultants are collaborating to create completely new transdisciplinary teacher and school leader preparation programs. Creating these programs involves creating completely new transdisciplinary STEM curricula for training Egyptian teachers in the various STEM school subjects and for training STEM school leaders. 141 new courses have been authorized by the Egyptian Ministry of Higher Education and must now be created to fill these new and radically different curricula. In addition, this round of funding supports the continued expansion of STEM schools, adding 13 more across Egypt.

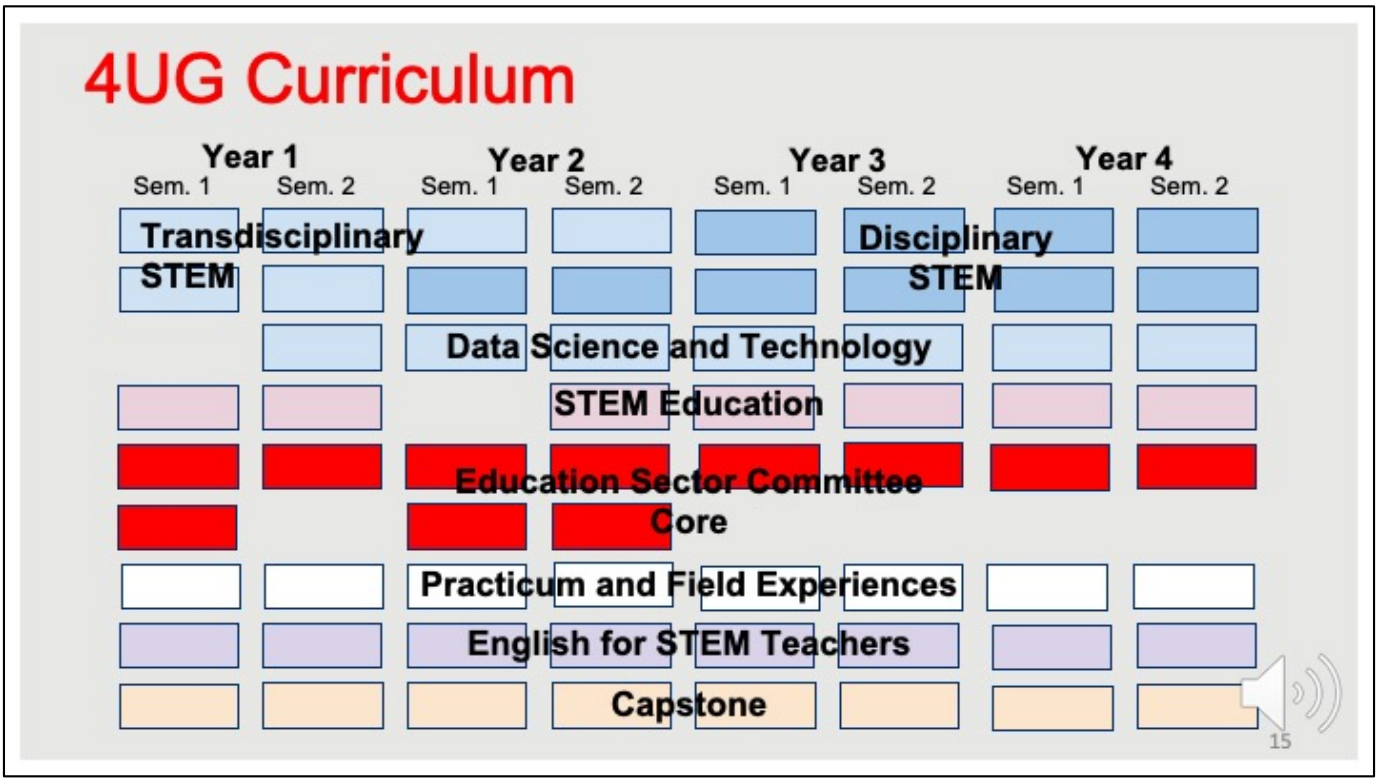
STESSA partners include 5 public universities in Egypt, Ain Shams, Assiut, Mansoura, Minia, and Zagazig Universities, and 5 universities in the US, Arcadia, Cal Poly, Drexel, Fresno State, and Temple, all coordinated by 21PSTEM.



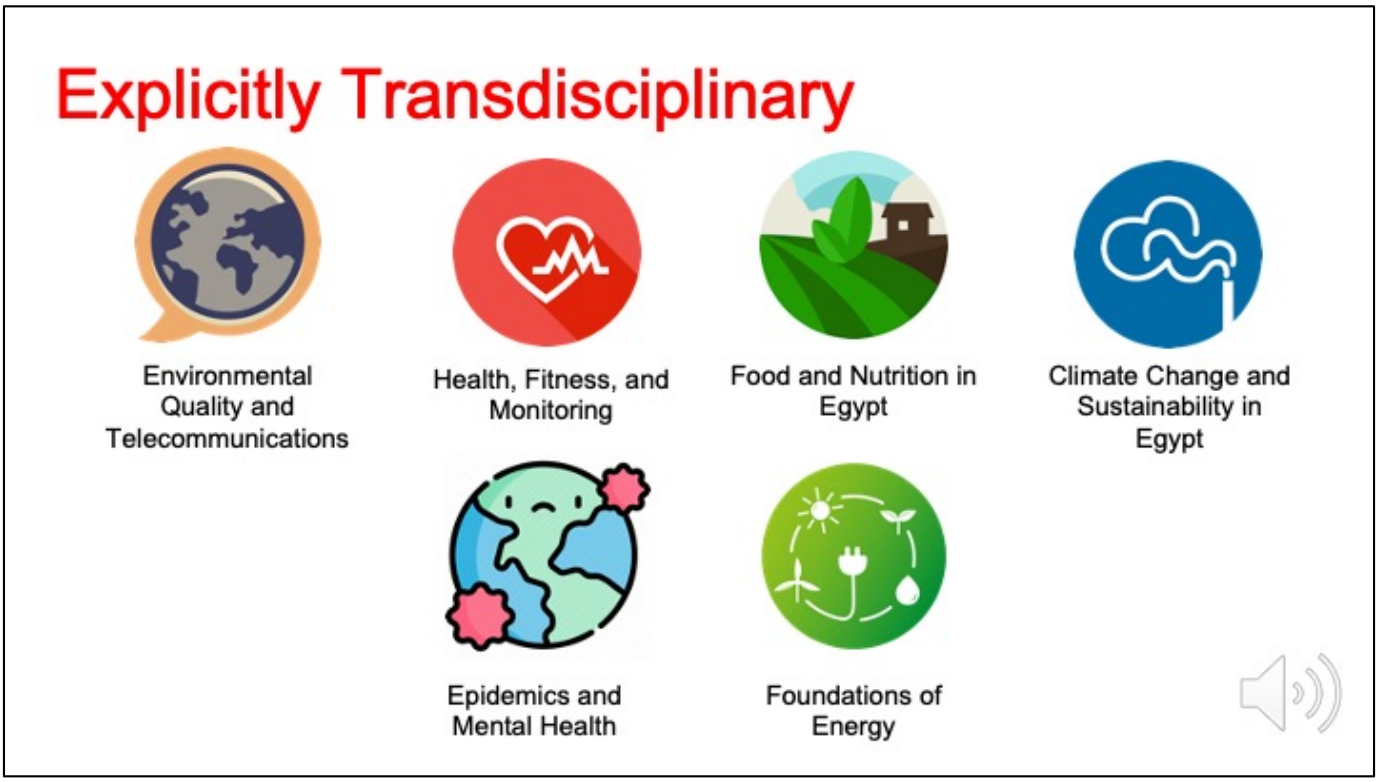
Our Grand Challenge then, is to meet the needs of schools that were in turn designed to meet the needs of Egypt. Early on, faculty developed a plan that replaced traditional disciplinary introductory courses, such as Physics 101, with a set of team-taught, completely transdisciplinary, STEM content courses, anchored in Egyptian phenomena and issues. The development of an entirely new curriculum, founded in a set of novel transdisciplinary STEM courses, across five different universities, through collaboration across international borders is a formidable task. Both American and Egyptian professors, as well as project staff, have been motivated in this task in no small part by the remarkable energy and capability of the STEM high school students themselves and their need for highly skilled and deeply knowledgeable teachers.



The new curricula form two different tracks into STEM school teaching. The first is a one-year Post-Baccalaureate track for STEM and Education graduates who want to enter STEM school teaching. This provides a basic introduction to STEM content, cutting-edge STEM pedagogy, and teaching and leading in the STEM school setting. The second, and our focus today, is a set of new 4-year undergraduate majors in STEM teaching. These new majors prepare teachers for each of the STEM school disciplines, physics, chemistry, biology, mathematics, and Earth science.

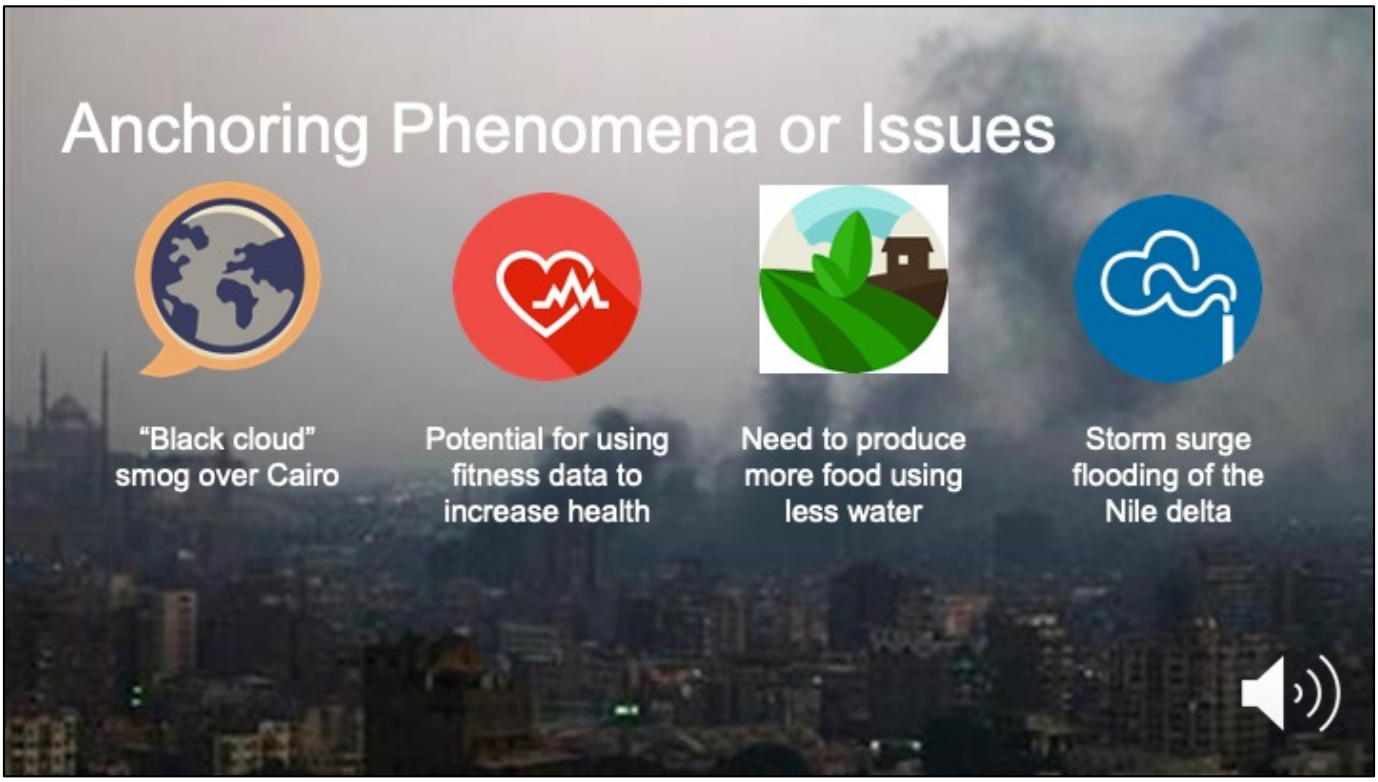


Given the importance and the success of the transdisciplinary capstones in the STEM high schools, we chose to double down on transdisciplinary experiences in the undergraduate curriculum. <click> Each of the new STEM teaching majors begins with the same six transdisciplinary courses, taught by teams of faculty from different disciplines. <click> These are followed by 10 disciplinary STEM courses. These courses are taught within a single discipline, but keep a transdisciplinary focus. In addition to 16 STEM content courses, <click> students take a course in data science every semester. The one blank you see is a data science course found in the Education Sector Committee Core courses <click> They take a course in STEM education every semester (again the missing one is an ESC core course). <click> They also take a teaching practicum, English for STEM teaching, and Capstone every semester. Egyptian students take more courses per semester than American students typically do and this is an action packed curriculum. It is also a significant course development challenge to flesh out all of these courses, most of which are completely novel, in a few years.



As mentioned, one of the most novel aspects of these curricula is the use of transdisciplinary courses to teach the basic science content that is usually covered in introductory science and math courses. These six courses are all derived from contemporary Egyptian issues and Grand Challenges and all approach their content through strands that cut across disciplines, such as the origin and importance of patterns, the role of scale, the flow of matter and energy in systems, and systems modeling, Environmental Quality and Telecommunications engages students in developing an environmental monitoring network, Health fitness and monitoring engages students in the use of sensors to track motion and the development of a fitness plan using those data, Food and nutrition looks at the sources of nutrients for people and at the chemistry of food and its preparation, and Climate Change and Sustainability looks at storm surge, heat waves, and carbon footprint. Epidemics and Mental Health and Foundations of Energy are second year courses that are currently under development.

The role of Earth system science is obvious in a course like Environmental Quality and Telecommunications, although the course integrates that content with electrical engineering, chemistry, biology, and physics, teaching foundational concepts such as combustion reactions, elementary statistics, basic GIS mapping, and wind and water flow. Geoscience professors have been involved in the design and teaching of all the courses and students explore basic ideas from geoscience in each of the transdisciplinary courses. Here you can see that geoscience ideas are even included in the Health, Fitness, and Monitoring course, although geoscience plays a much less significant role in that course, which is heavily biology and physics oriented. It was never the intent to have every transdisciplinary course give equal weight to every STEM discipline. Rather, our goal was to use the connections of different disciplines to issues in Egypt to craft a series of courses that, in toto, would provide a solid introduction to STEM concepts, no matter what discipline a student chose to concentrate in.



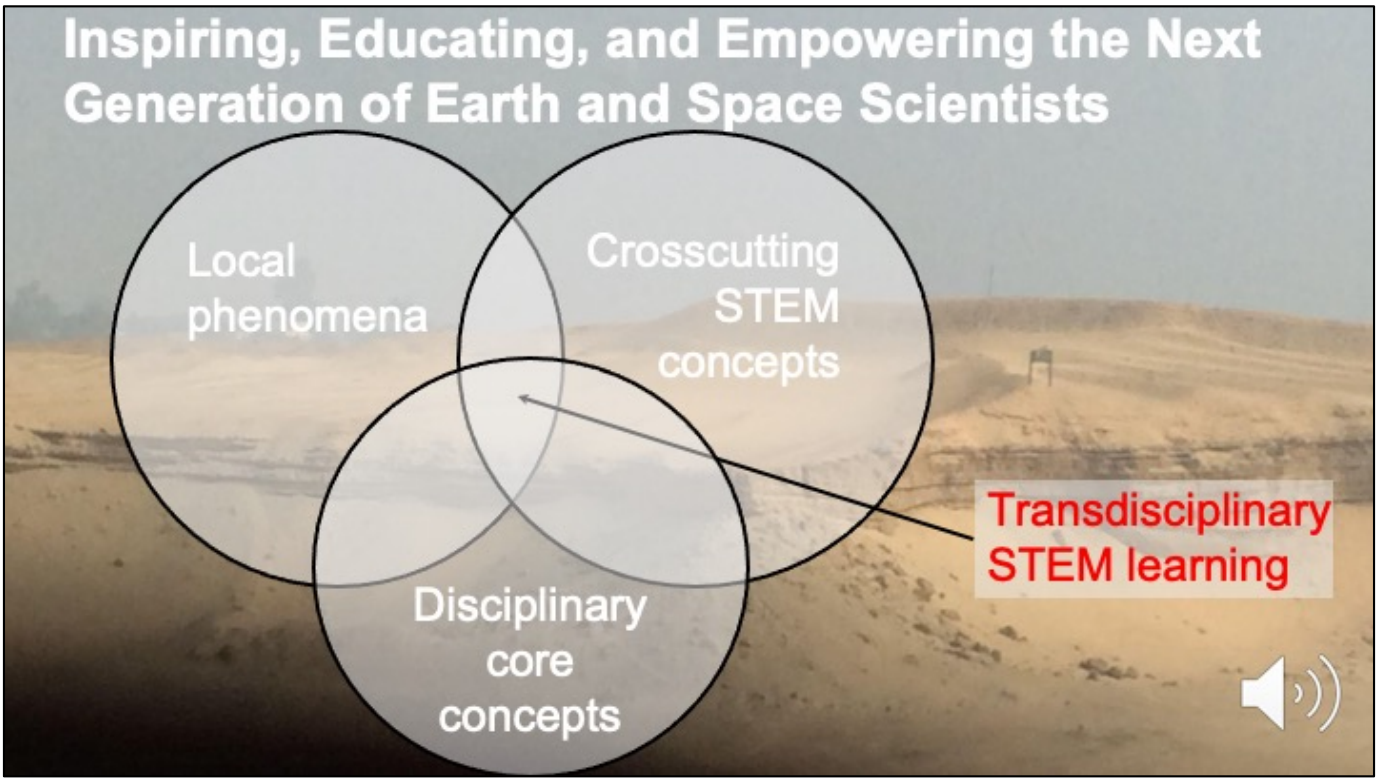
The transdisciplinary courses are all drawn from local issues or phenomena. These phenomena have several important attributes for the course development process. They are readily identified by our Egyptian colleagues, they provide motivation for both Egyptian professors and Egyptian students to engage with content in an unfamiliar context, and they are inherently transdisciplinary. This makes these phenomena ideal vehicles to bring together disciplinary faculty in ways that might otherwise be difficult to facilitate. And for Earth scientists, it means that Earth science has a vital role in the foundational science education of all STEM school teachers in Egypt, no matter what discipline they might be studying. This is a part of the curriculum development process where our Egyptian colleagues played a pivotal role. For example, US faculty, in our initial planning for the environmental quality course, imagined a range of environmental issues that could be the focus of the course. Our Egyptian colleagues, however, very quickly focused on air quality as the key issue for the course and were able to identify phenomena such as the "black cloud" of photochemical smog resulting from rice straw burning as anchoring phenomena for the course.

Implementation So Far

In the first two course, faculty report that students and faculty:

- Had an adjustment period to co-teaching and to learning from multiple professors
- Have dealt with delays and challenges in procuring equipment, but have innovated to keep courses on track
- Are excited and engaged by studying local issues

After a lengthy design process with iterations by US faculty and by Egyptian faculty followed by additional professional development of Egyptian faculty, the first two transdisciplinary courses are currently being offered at 5 Egyptian universities. As many as 40-60 students per university are enrolled in each of these courses, and initial reports are positive despite challenges. As you are all aware, COVID-19 has led to supply chain issues everywhere in the world, and our equipment orders for these new courses were no exception. Happily, some Egyptian professors and students have been eager to innovate and work around a lack of some equipment. We hold regular meetings with Egyptian faculty teaching these courses to explore their experience and offer support. In those meetings, we have heard some great stories of students and faculty both being excited and engaged by the transition from rote lecture-based learning to more investigational and interactive learning. For example, we hear that students in the Environmental Quality course are very interested in studying air quality in their own neighborhoods. We have all also learned that crossing disciplinary boundaries and international borders at the same time is hard work, and rewarding work at the same time. The students are what keep us all going and their enthusiasm is an important driver of change.



Our take-home message is this. Combining local phenomena with cross-cutting STEM concepts such as patterns or models and disciplinary core ideas will almost inevitably yield rich transdisciplinary STEM learning. We have seen this approach yield success in our first two transdisciplinary introductory STEM courses, across 5 universities and over 100 students. Our preliminary results are very hopeful that this approach can create new introductory courses that engage students from diverse perspectives in building foundational understandings of the Earth system and inspire those students to continue learning and teaching others as they attempt to solve Grand Challenges, regardless of where they live.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