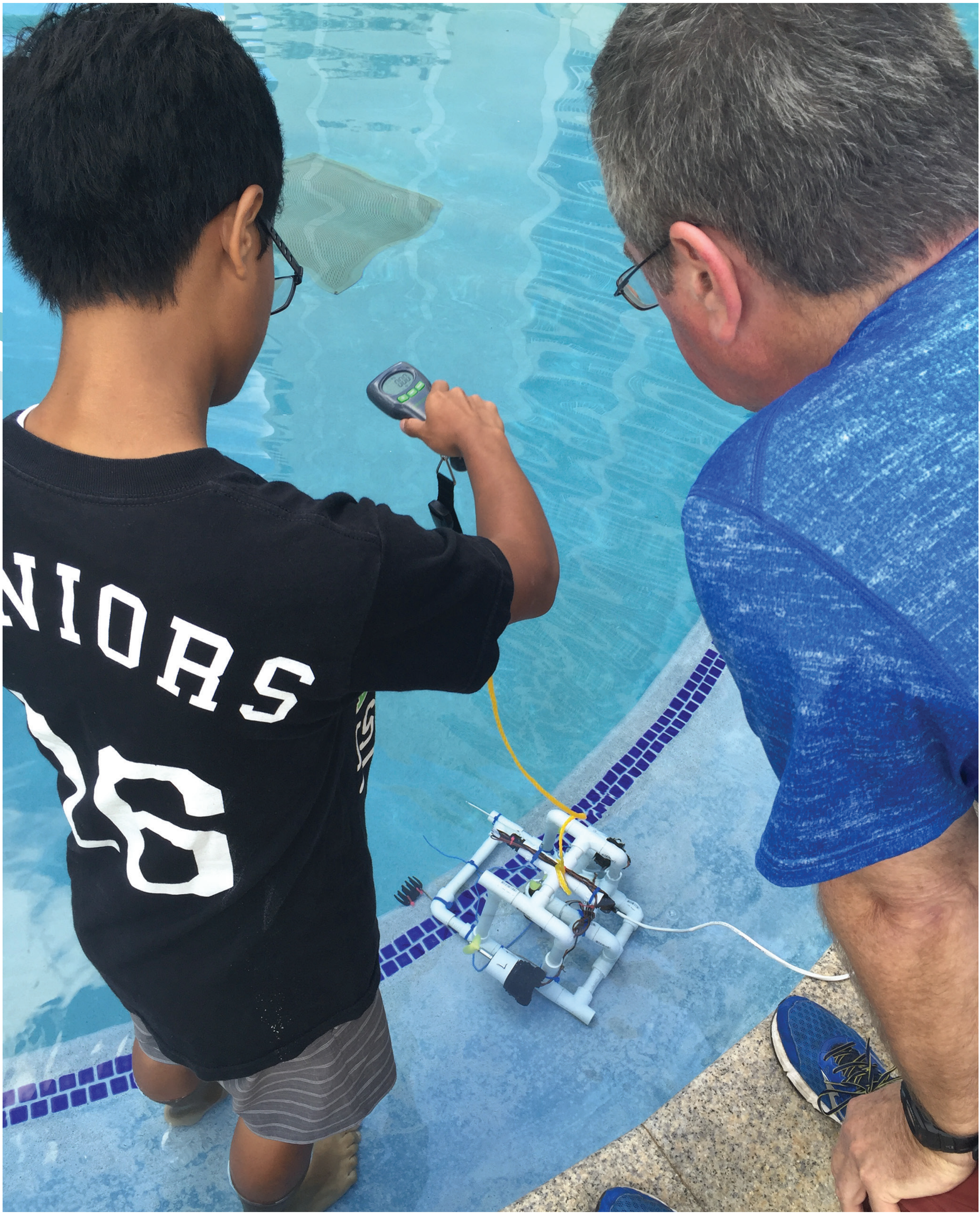


Photo by ANNE TWEED

A Guam High School student tests the buoyancy of his remotely operated vehicle with the assistance of retired engineer Jim McDonnell during the Marine Advanced Technology Education underwater robotics professional learning experience.

DIVING BENEATH THE SURFACE

UNDERWATER ROBOTICS LESSONS BRING STEM TO LIFE FOR TEACHERS IN GUAM

BY ANNE TWEED AND LAURA ARNDT

In spring 2014, education leaders from across Micronesia came together on the island of Guam to learn about underwater robotics and Marine Advanced Technology Education (MATE), a program based at Monterey Peninsula College in Monterey, California.

Participants listened intently as they learned about building and participating in competitions with Remotely Operating Vehicles (ROVs) outfitted with tools that could capture images underwater, collect water samples, and gather artifacts from the bottoms of swimming pools.

Underwater robotics may not seem that exciting to educators in landlocked areas, but for this group, it sounded like a perfect way to build students' content knowledge in STEM (science, technology, engineering, and mathematics) and GreenSTEM (STEM focused on environmental sustainability) to learn skills that can be applied in the real world.

In Guam and across Micronesia — where students haven't had many opportunities to pursue STEM careers — underwater robotics engineers are often hired from off-island to maintain or repair underwater installations. Also, such engineers are in demand globally to work as underwater robotics technicians, mechanical ocean engineers, engineer scientists, and marine machinists and welders.

Encouraged by the potential of the marine technology program, and armed with the results of a needs-sensing survey that showed high interest in STEM education and careers across Micronesia, educators focused on two critical questions:

1. Will the marine technology curriculum and competition engage middle and high school students from Pacific Island nations and increase the number of students interested in pursuing STEM learning and careers?
2. Can STEM teaching and learning — and programs like MATE — be modified to effectively incorporate

GUAM STEM PLANNING FRAMEWORK		
PROCESS STEPS	**ACTIVITIES**	**FINDINGS THAT INFORMED THE ONGOING PROCESS**
1. Set the stage	a. Identify current thinking about STEM. b. Identify current STEM challenges. c. Define the purpose of the STEM initiative.	This allowed the strategic planning team to take stock of what they believed about STEM and why it was important for them and their students. STEM to them was more than just an educational trend.
2. Develop understanding about STEM models in general.	a. Review research about STEM models and their effectiveness. b. Identify appropriateness of various STEM models for the context.	Before deciding the approach to STEM, the team reviewed the effectiveness research associated with the following four models: integrated STEM; STEM magnet schools; STEM school-within-a-school; and out-of-school-time STEM programs.
3. Develop understanding about STEM programs in the context.	a. Develop or adapt questions to gather information about existing STEM programs in the context. b. Analyze data from the survey of existing STEM programs and summarize findings.	This step was to gather data through a survey of existing STEM programs on Guam. Through their analysis, they determined which programs could be leveraged across the district and be sustainable.
4. Develop a definition of STEM for the context.	a. Draft an initial definition of STEM. b. Gather feedback from stakeholders. c. Revise the Guam STEM definition.	It was important to develop a common definition of STEM for their context that was based on the models.
5. Develop a vision statement for STEM in the context.	a. Draft an initial vision statement. b. Gather feedback from stakeholders. c. Revise the vision statement.	Without a clear vision, the proposed outcomes identified in the strategic plan wouldn't make sense.
6. Develop a set of goals to achieve the vision.	a. Draft an initial set of goals. b. Gather feedback from stakeholders. c. Revise the set of goals.	The initial set of goals was revised many times based on feedback from the region. Ultimately, it was aligned to goals from the Guam Department of Education's State Strategic Plan and became part of a broader coherent effort.

indigenous learning and the cultural and natural environment of students, teachers, and the community?

For Guam's Department of Education, the answers were yes. But in the weeks that followed, it became clear that, although teachers had already had several STEM trainings and the district had three STEM-designated schools, the Department of Education and teachers across the district still had questions: What exactly was STEM, how could it be implemented effectively, and what professional learning practices were needed to sustain a STEM initiative?

To get clarity, the Department of Education knew it needed to be strategic about its approach, and so district leaders reached out to the MATE planning meeting facilitator from McREL International for support in developing a plan. That set into motion what would become a two-year project to plan, develop, and implement culturally responsive professional learning at the elementary, middle, and high school levels that would bring STEM to life for teachers across Guam and, ultimately, for their students.

TEACHERS TAKE OWNERSHIP

In Guam, most of the professional learning teachers and school leaders experience is packaged, meaning they learn about a specific program — usually not culturally relevant — and how to implement it during a one- to three-day session. Often, once the session is over, teachers are expected to implement the new program without additional ongoing professional learning. The Guam STEM project took a different approach, using an inside-out model that put educators and their context at the center of the planning and decision making, with sustainability as the goal.

The planning framework shown in the table above and on p. 33 guided the work of the STEM strategic planning team. This nine-step, iterative process is one that they can use going forward to

GUAM STEM PLANNING FRAMEWORK, continued		
PROCESS STEPS	**ACTIVITIES**	**FINDINGS THAT INFORMED THE ONGOING PROCESS**
7. Develop a logic model for achieving the STEM goals.	a. Develop understanding of the elements of a logic model. b. Identify the strengths and challenges related to each of the goals. c. Identify the key challenge(s) related to each of the goals. d. Identify the root cause(s) of each of the key challenges. e. Identify short- and mid-term outcomes of addressing the root cause of each key challenge. f. Identify activities that will lead to achievement of the outcomes. g. Identify resources that will support achievement of the outcomes (considering the strengths and other resources).	The strategic planning team had not experienced creating a logic model and had to learn about inputs, outputs, and outcomes. It gave structure to the initiative so that their plan was not merely a list of activities but had clear, short-, mid- and long-term outcomes, with accompanying ways to measure progress. They used this as a dynamic document and sought feedback and public comment that involved everyone in the process.
8. Develop an action plan for carrying out the activities in the logic model.	a. Develop understanding of the components of an action plan, if necessary. b. Create an action plan for each major activity; include timeline, person responsible, resources needed, success measures, and targets.	With the support of the superintendent, professional learning activities aligned to the goals have occurred throughout the strategic planning process.
9. Evaluate the approved strategic plan and goal-based activities and develop a monitoring plan.	a. Develop understanding of a monitoring plan. b. Create a monitoring plan and use it to guide the data collection and evaluation of progress toward outcomes. c. Revise the implementation goals for the next year.	A monitoring plan with targets is guiding implementation efforts. The strategic planning team is now the implementation team focused on making the STEM efforts sustainable and available to everyone.

create and implement a strategic plan for any improvement initiative.

What the team found most effective about this framework was that it allowed them to take ownership of the process, making decisions that lead to authentic and relevant STEM experiences for teachers and students. They were able to create a vision and goals that reflected their island perspective. They could connect local environmental issues to the STEM content and make clear connections to jobs. They had opportunities to revisit decisions and documents and revise as they saw fit.

LOCAL CONTEXT

Once the team identified its STEM goals (step 6 in the table on p. 32), facilitators and district leaders began developing targeted professional learning experiences through a process of asking questions, talking about island-specific needs and challenges, and discussing culturally relevant options during ongoing conversations (steps 7f and 7g in the table above). What the facilitators called "initial listening sessions" helped bring to light the unique issues of the schools, local community, and natural environment in Guam. Questions included:

- What are you most proud of (in your schools, in your island communities, for your unique natural environment)?
- What are the most pressing concerns or problems?
- If you could change one thing to improve your school, island communities, and natural environment, what would it be?

Responses to these questions were starting points for building STEM professional learning, using the organizer shown on p. 34.

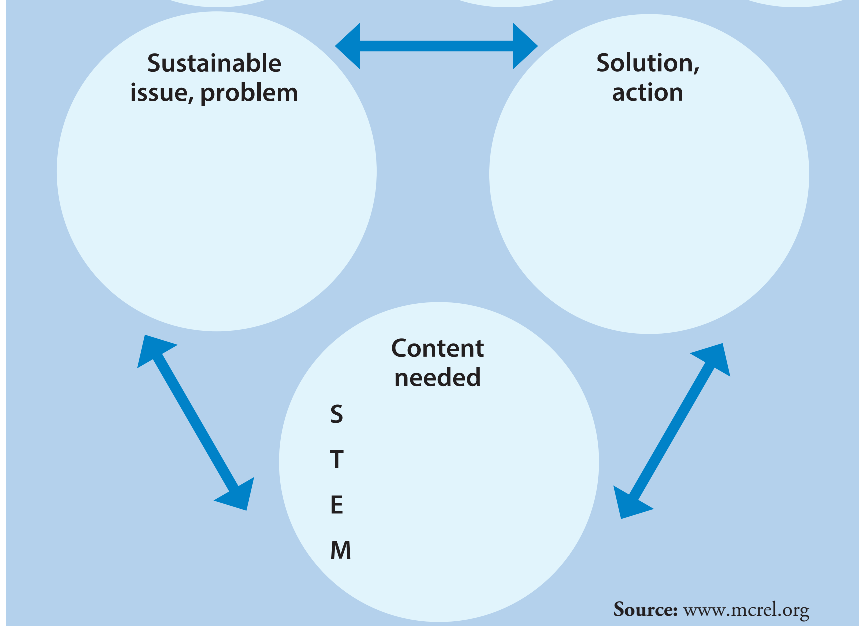
Educators at each level determined their priorities for professional learning (see the table on p. 35). Elementary teachers wanted to strengthen their content knowledge and STEM instructional skills, so their first step was to select a prepared curriculum that addressed desired grade-level content through best science practices, the engineering design process, and the Next Generation Science Standards. Then they integrated STEM activities that addressed island issues and problems, making the professional learning authentic and culturally relevant.

The middle school educators focused on a sustainability issue specific to Guam. When asked for their biggest island concern, the response was, "We have very little locally grown fresh foods, so it is harder for kids and families to make healthy choices." Teachers suggested the solution of student-designed aquaponics systems that create a mutually beneficial relationship between edible plants grown in water (hydroponics) and aquatic animals raised in an enclosed container (aquaculture). An additional goal was to purchase all materials on island. Finally, they chose activities that addressed the science content needed to build and use aquaponics systems, grow edible plants, and raise local tilapia.

The high school professional learning focus began with the goal of building and using underwater robots, or ROVs. Teachers easily generated a lengthy list of inland and coastal water issues and problems that could be investigated with student-designed ROVs. Though some of the content would depend on the issues selected to investigate, construction of ROVs is steeped in engineering design and physical science concepts.

An advance organizer for focusing professional learning

BUILDING A GREEN STEM FOCUS



Source: www.mcrel.org

TEACHERS AS LEARNERS

A key part of the professional learning design at all grade levels was having teachers experience what their students will experience, thus giving them a model for how to introduce the steps of a GreenSTEM instructional approach in their classrooms (for more on this approach, see Arndt, 2016).

In addition, while designing and redesigning solutions to their questions, teachers experienced an intentional shift in control, from the facilitators to them — which models the shift they are encouraged to make with their own students. Participants experienced the joys and struggles of authentic science and engineering — trying design ideas that did not work, making mistakes, collaborating on new ideas, and celebrating aha moments and successes. Teams of teachers gathered new ideas online and consulted with other teams. When they ran into roadblocks, they brainstormed new solutions. It became their responsibility to tell the facilitator what additional materials or expert support they needed.

The Guam STEM project used an inside-out model that put educators and their context at the center of the planning and decision making.

Providing choices and allowing participants to take full control of their actions created a culture of co-learning that is a feature of the ideal STEM classroom. Initially, some teachers expressed anxiety and frustration with this shift of roles, but as they moved through the process, they began to own their learning, and their self-esteem and enthusiasm grew. The learner's thinking shifted from "The facilitator (or teacher) will tell me the correct answer" to "I have the ability to figure this out myself by trying again and by getting help from peers, community stakeholders, and experts."

The shift in the facilitator's or teacher's role to that of coach, mentor, and networker opens opportunities for relationship building between teachers and other stakeholders in the

BUILDING PROFESSIONAL LEARNING EXPERIENCES			
	Elementary school	Middle school	High school
Sustainable issue or problem	Skin and eye damage from sun in their tropical location.	Need more locally grown fresh food to improve students' health choices.	Overfishing and the need for marine life surveys and monitoring the health of the coral reefs surrounding the island.
Solution to issue or problem	Use ultraviolet-sensitive beads to test the most effective clothing and glasses for protecting the body.	Build aquaponics systems to raise local tilapia and grow edible vegetables and fruits.	Build marine robotics systems to use in the island's fresh and coastal marine waters.
Content needed to understand issue and design solution	Teach light concepts that include the electromagnetic spectrum of light.	Teach life science, chemistry, and physics concepts needed to understand the issue and successfully grow food.	Teach chemistry, physics, and life science needed to build and use the ROV and to understand the issues.

community. For example, the middle school teachers had video chats with a California teacher who not only designed but also taught using the aquaponics system brought to Guam. The executive chef of a Guam hotel made repeated visits to the sessions, eagerly offering his support to work with teachers on preparing dishes with the food they grew.

A retired engineer with a long history of building and using ROVs with teachers and students came to co-facilitate the training. A local scuba diving master and solar energy expert gave presentations directly related to the work being done. Relationships with these stakeholders help support teachers and schools long after the professional learning ends.

NEXT STEPS AND LESSONS LEARNED

After each professional learning session, teachers left with materials and strategies to begin piloting the Guam STEM curriculum and projects with their own students. As implementation continues in the next school year, participants will receive follow-up coaching and share what they've learned by beginning to teach their colleagues about the STEM framework and process.

Schools are acquiring the necessary materials, technology, and curriculum

The key element in this project was not materials or technology but building relationships.

that will allow students to gather more accurate data, expand their investigation opportunities, and build more ROVs and aquaponics systems. The district plans to align the Guam STEM projects and its curricula to the Next Generation Science Standards; create an online management system that will house all Guam STEM professional learning support documents, lessons, and instructional materials; and provide chat rooms for sharing successes and collaborating to solve problems.

The Guam STEM project has not been without its challenges — even with careful planning, it was difficult and costly to ship STEM materials to a remote Pacific Island location — but having an innovative, teacher-centered professional learning format that intertwines STEM content, local culture and issues, and sustainable solutions should be challenging.

Overall, the key element in this project was not materials or technology. Rather, it was building relationships of mutual respect and understanding among the teachers, community, and natural environment. When facilitators or teachers step off the "I am the expert" pedestal and onto the "I am part of your team" platform, everyone is acknowledged for the expertise and experience they bring to professional learning or the classroom — and then all that was thought to be a challenge becomes the bridge to success.

REFERENCE

Arndt, L. (2016). *GreenSTEM Model: Steps for an instructional approach [Blog post].* Available at www.mcrel.org/greenstem-model-steps-for-instructional-approach.

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