Learning math is as simple as 1-2-3. Even primary school kids can grasp the basics, given the chance. But you won’t find Dr. Jonathan Brendefur drilling 6-year-olds on times tables. Instead, he’ll more likely encourage them to play with wooden blocks and use mathematical language to describe what they see as a subtle way to introduce mathematical concepts.

Brendefur is a professor of mathematics education at Boise State University and director of the Initiative for Developing Mathematical Thinking. IDMT currently hosts two grants: A U.S. Department of Education Mathematics and Science Partnership award that works with elementary and middle-school teachers and staff, and a grant from the Idaho State Department of Education to provide mathematics professional development to thousands of K-12 teachers and administrators across the state.

Idaho standardized testing begins in the third grade, but preparing kids to be analytical thinkers starts as early as kindergarten. That’s why Boise State educators are actively seeking to better understand how children learn math and science, and how the many new teachers the College of Education graduates each year can be better prepared for the classroom.
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While teaching math once focused primarily on numbers and symbols, educators now know that spatial reasoning — the ability to think about objects in three dimensions and draw conclusions about them — also is a critical component in mathematical thinking.

“Spatial reasoning helps us investigate and solve complex problems,” Brndefur said. “For instance, could you think about a rectangle, mentally dissect it diagonally, then rotate the top triangle 180 degrees? Are you able to then see that the area of a triangle is half of its length times its width (because it is half of a rectangle)?”

Letting kids manipulate objects is a crucial first step in getting them to visualize those objects as pieces of a math puzzle. The same general hands-on concept applies to science teaching, where engagement is supplementing, and even taking the place of, textbooks.

“We know that it’s not just the content that matters, it’s the engagement,” said Dr. Julianne Wenner, an assistant professor in the College of Education. “It’s important to think about how to engage kids and help them understand why something works the way it does.”

As a former K-12 teacher, Wenner noted that science can appeal to many students who may not otherwise feel successful in the classroom. “There are kids who don’t memorize or test well, but they can do science,” she said.

When science is taught well, it encourages a way of thinking and approaching the world that lets students pursue a thought rather than being told what to think.

Wenner and colleagues Sarah Anderson and Sonia Galavaz have been working with students at Garfield Elementary School near the Boise State campus. Their project, funded by the NASA Idaho Space Grant Consortium, aims to make science more meaningful for children both inside and outside of the classroom.

G-FORCES (Garfield Families Optimizing Regional Connections and Engaging in STEM) provides resources such as an annual family science night, backpacks filled with supplies for science activities kids can check out and do at home with their families, and lists of local family-friendly resources like the Discovery Center of Idaho, the Boise Astronomical Society or the World Center for Birds of Prey.

“G-FORCES helps families see they don’t need a special degree to talk about science,” Wenner said. “Kids can ask questions like ‘Why do tree leaves turn colors?’ or ‘Why does a hot air balloon rise?’ and then find the answers.”

Science education assistant professor Dr. Sara Hagenah argues that a critical part of this learning process involves how those questions are framed. Where teachers used to be the ones asking questions, educators are now looking at what happens when students assess what they know about a subject and then ask questions based on what they don’t know.

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For instance, students discussing the implications of a scientific idea might ponder how it taps into a naturally occurring phenomenon. How does the Earth’s tilt affect how we experience seasons vs. people in Australia? If the Earth’s tilt were changed, would that affect our seasons? How?

By stopping to consider what questions they have about a specific phenomenon, students are motivated to find evidence to support scientific hypotheses. “This leads to students talking about rigorous scientific ideas,” Hagenah said. “It allows teachers to be responsive to student ideas rather than just asking students for a right (or wrong) answer to a question.”

Furthermore, Hagenah believes these are skills that can be taught to new teachers. “Teacher candidates practice how to facilitate this type of learning in our teacher education programs,” she said. “University students can walk out and be ‘expert-like’ teachers who know how to elicit student thinking and build rigorous science explorations.”

One way for them to do that is to not be afraid of looking outside of the classroom for answers, said associate professor of education Dr. Leslie Atkins Elliott.

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“What makes science boring for students is when they assume that every question has answers that will be provided in the lab, in the back of the book or in the lecture,” she said. “That restricts what counts as a good question, what can count as evidence, and where students expect to see and use scientific ideas.”

Instead, Atkins Elliott said it’s important to encourage the belief that science is creative and relevant to everyday life. Inspired by the maker movement, she regularly sends education students to the MakerLab in Albertsons Library to learn how to construct their own materials that can help them support or dispute scientific claims. She also wants them to consider how, by “making” artifacts, students actively construct their own scientific ideas.

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“If they have to physically make something that works, they will have an understanding of the deeper, conceptual kinds of questions students might ask,” Atkins Elliott said.

But how do you get teachers on board with these more interactive learning styles? It helps when they can see results. Dr. Keith Thiede, associate dean of the College of Education, worked on a recent project aimed at helping elementary school teachers more accurately monitor kids’ learning. The project was funded by a $1.2 million grant from the U.S. Department of Education.

“We showed that teaching using the Developing Mathematical Thinking framework of instruction, developed by Brendefur, helped teachers much more accurately monitor their students’ learning, which helped them target instruction at levels better tailored to the needs of students,” Thiede said. “Perhaps most importantly, this approach to teaching mathematics has led to significantly greater gains in achievement.”

Mathematics educator Dr. Joe Champion said that teachers around the state have come to equate the ideas of modern best practices for teaching mathematics in the early and middle grades with Mathematical Thinking for Instruction, the signature course designed and delivered by DMT to nearly all teachers in Idaho.

To date, more than 13,000 educators have taken the course, and Champion said that data shows this has made a profound impact on teaching statewide.

“This has given the teaching community a shared understanding, a shared language for talking about students’ thinking and learning, and an almost unheard-of widespread appreciation for why the ‘tried-and-true’ traditional ways of teaching mathematics need to adapt to the new sets of knowledge and skills needed for success in our 21st century economy,” he said.

Dr. Michele Carney, associate director of the Initiative for Developing Mathematical Thinking, notes that professional development goes hand in hand with assessment.

“We have good work in professional development, but not good measures,” she said. “We need better assessments at both the teacher and student levels.”

Carney, whose work focuses on data analysis, said it’s important to make sure that kids cannot only solve a problem, but conceptually understand ideas. “It’s about engaging kids to use math in meaningful ways,” she said.

“When mathematics is taught well, kids shouldn’t have to ask why they need to know it. How it is taught makes it useful or not useful in life. A student’s ability to perpetually reason is a huge indication of future success.”

For Brendefur, that process can’t start soon enough. “By fourth grade, there’s already a difference between those kids who do math and those who don’t,” he said.

And with so many future jobs tied to the ability to analyze data, it’s more essential than ever for teachers to find ways to engage kids in analytical thinking. Until that happens, he’ll continue reaching out to local teachers and kids, one building block at a time.

“If math is just calculation, then we have electronic devices to help us with that. But mathematics is more about spatial reasoning and problem solving. Math gives us a way of describing what we are seeing in the world around us,” he said. “It’s not just algorithms, it’s understanding that everything in our environment is mathematical and then doing something with that knowledge.”