STEAMpower: Inspiring Students, Teachers, and the Public

edited by Deirdre Helfferich, Jan Dawe, Zachary Meyers, & Nancy Tarnai

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Final journal for the Alaska EPSCoR StoryTelling project conducted by BAKLAP's K–20 STEAM Education program. This journal was created by an eighth-grade student at Effie Kokrine Early College Charter School, from the paper to the finished piece.
—PHOTO BY ZACHARY MEYERS

STEAM: Science, Technology, Engineering, & Mathematics powered with Art

Kindergarten through graduate education (K–20) in the sciences, technology, engineering, the arts, and math is of utmost importance to innovation and creativity in design. STEM fields are all traditionally left-brained, logic-oriented endeavors. They develop critical thinking skills, and are lauded for their importance in building a strong economy. The arts, however, are right-brained, and contribute to creativity and invention and develop not only critical thinking skills but also critical making skills—all important to success in technical fields as well as the fine arts.

STEAM education is a means of exciting students, teachers, and the public, and motivating them to become learners for life, involved and inspired with an inquiry-based approach to learning. Learning happens everywhere: in formal settings, such as classrooms, workshops, apprenticeships, and during on-site job experience; in informal settings, including after- and out-of-school programs, field trips, museums, zoos, botanical gardens, galleries, on vacation, and through hobbies and digital and online resources; and in more unstructured, playful environments, too. Wherever it occurs, learning is a cumulative, never-ending, lifelong process. STEAM education is suited to all these formal and informal settings.

STEAM education empowers individuals to pursue their own interests at their own pace. It's also not exactly new: the perfect example of STEAM thinking is embodied in Leonardo da Vinci's approach to integrative learning and invention. While not everyone can be a da Vinci, anyone can be a critical thinker and maker through practicing these principles.

While integrated education can be part of a normal curriculum, in STEAM education, the hands-on, creative aspect is stressed and becomes a means of creating a broader, deeper understanding of all the other parts. Each activity explicitly relates to a specific subject area or topic that is the focus of exploration. For example, if the topic is botany, the students may explore a plant's biology through sketching its anatomy, discover physics or math through learning about the amount of water needed to maintain turgor pressure, and learn technological skills when they document changes in the plant through a time-lapse video. All these experiences offer different perspectives on what is happening with the plant and how it is growing.

In the UAF School of Natural Resources & Extension, the Boreal Alaska—Learning, Adaptation, Production (BAKLAP) K–20 STEAM education program, directed by Dr. Janice Dawe, uses four methodologies—integrated curriculum, K–12 teacher professional development, peer teaching, and community collaborations—to fulfill its educational mission:

> *To improve STEM teaching and learning outcomes by developing model integrated K–12 curricula based on hands-on experiences with the Alaska boreal forest through inquiry science and art.*

OneTree Alaska is the model for STEAM education, connecting the university with K–12 schools, teachers, and students. As part of BAKLAP, OneTree Alaska is developing curricula through classroom activities (e.g., Tapping Into Spring) and special projects such as the Forest Entrepreneur Camp, and as a result of teacher professional development courses and citizen scientist field training.

Classroom activities & special projects

The BAKLAP K–20 STEAM Education program classroom activities range from studies of germination and tree growth experiments, to investigating competition among maternally related lineages in Alaska white birch (*Betula neoalaskana* Sarg.). The core curriculum includes scientific inquiry and observation studies and the Tapping Into Spring program. Special projects include collaborative instructional design projects such as an interactive mural and altered books. None of these are isolated from each other: the very nature of STEAM education, from K–12 classrooms up to adult community courses, is to create connections and collaborative work. Teachers from a dozen different elementary and middle schools in the Fairbanks North Star Borough School District have worked with BAKLAP since 2012, with new schools and teachers joining each year. The origins of this classroom work date back to efforts by the Alaska Boreal Forest Council from 1998–2005, and by OneTree Alaska from 2009–2012.

Classroom visits, university service learners, and UAF coursework

To make the program work, the STEAM personnel are committed to customizing lesson plans and activities to suit grade-level curricula and teachers' special topic focus areas, and gathering ongoing feedback and evaluations to improve the program from one year to the next. Classroom visits are an important part of the K–12 work, with scientists and graduate student service learners going to classrooms to work directly with teachers and students. K–12 teachers have commented repeatedly how much they appreciate having scientists and university graduate student service learners come into their classrooms, saying how inspiring these interactions are for students.

Service learning is a teaching and learning strategy that integrates meaningful community service with instruction and reflection, and is designed to enrich the learning experience, teach civic responsibility, and strengthen communities. A graduate level resource management course at SNRE, Independent Study in Natural Resource Service Learning, offers a platform for a "community of learners" such as Peace Corps Master's International degree-seeking

students, a UAF alumna seeking her K–12 art teacher's certification, and more. The graduate student course is paired with a companion professional development course taken by borough schoolteachers. An example is "OneTree: From Seed to Tree," which focuses on supporting teachers working with OneTree Alaska to grow trees in their classrooms as a means to integrate student explorations of science, technology, math, art, and stewardship concepts. Together, these courses create a cohort of mutually supportive teachers and students who support each other's efforts both to teach and to learn and to support their community, adding a collaborative breadth and depth to both K–12 and university coursework.

Peer teaching has been a hallmark of OneTree Alaska since 2009, and has been further developed as a teaching methodology by the STEAM Education program. Student peer teaching gained new heights during the 2013–2014 school year. Teachers at Tanana Middle School and Salcha Elementary worked together to create a middle-school level service learning program, independent of BAKLAP's K–12 STEAM Education program. Carri Forbes, a Tanana Middle School science teacher, wrote a successful proposal to State Farm Foundation to initiate a service learning program at her school. Her seventh-grade students worked with Ronda Schlumbohm's third-graders on the "Family Matters" experiment and "Tapping into Spring." Students from both grades spoke enthusiastically about their work together, and the peer teaching paid off: the third-graders took the top prize at the Interior Alaska Science Fair with their presentation of their "Family Matters" experiment.

Peer-to-peer mentoring worked well for Forbes' seventh-graders and Schlumbohm's third-graders.
—Photo by Zachary Meyers

"Tapping Into Spring"

Deirdre Helfferich, Nancy Tarnai, Jan Dawe

"Tapping Into Spring" is a curriculum project developed by Jan Dawe and the staff of the Alaska Boreal Forest Council from 1999–2005, with a curriculum kit of ten lessons created in 2003. The BAKLAP K–20 STEAM Education staff integrated its lesson plans into other OneTree Alaska curricular offerings, thus providing teachers with the resources to guide their students in understanding the spring phenology of birch trees, ways in which people use birch sap, and a means to practice citizen science. Through these activities, students employ the scientific method, develop math and writing skills, and practice making scientific observations.

The activity of tapping birch trees for sap each spring brings seasonality and tree physiology alive for K–12 students and adults. Even the toughest middle school students seem

Zachary Meyers, OneTree Alaska instructional designer, tapping a birch in preparation for the 2014 Earth Day demonstration event hosted by Carri Forbes' Tanana Middle School class. The theme of the event was "Sap to Syrup: The Birch Way."
—Photo by Nancy Tarnai

to connect to their trees with real gratitude when the sap runs for making birch syrup. Sound stewardship makes sense, perhaps for the first time, for many students. They're involved in a reciprocal relationship with the tree and, by extension, with the forest. It comes as no surprise that every school that participated in Tapping Into Spring during the previous school year wanted to do so again the next year, and teachers from additional schools are inquiring to see if there's room for them as well.

Tappers (called "sapsuckers" in the trade) agree that the primary hindrances to producing high-quality birch syrup and developing a stronger birch sap industry in Alaska are the high cost of fuel oil to process sap and the near-certainty of scorching sap and creating bitter syrup when the sap is boiled over direct heat. Reverse osmosis machines are used to reduce processing time, but cost thousands of dollars and are often far too large for backyard or small-scale syrup makers.

As part of her independent study work for her master of science degree, service learner and Peace Corps Volunteer Tricia Kent decided to renovate the old Northstar Syrup Works sugar shack, originally purchased in 2000 as part of the original Tapping Into Spring program. The renovation would have used waste steam from the UAF power plant to heat the sap for evaporation into syrup, whereas before it required no. 2 fuel oil. Kent wrote about the project, "Renovating the Sugar Shack is valuable due to its potential for educating students and the community about syrup making, alternative energy, and the value of our forests. …This project combines many of my interests including community-based natural resource management, education, and engineering design," she said. "Steam-powered syrup making is not a new technology, but will provide exciting challenges due to the integration of existing steam sources and evaporator equipment into one cohesive apparatus. Additionally, this project has the potential to contribute to community development in the future, which makes it an appealing project for me."

Kent consulted with syrup makers and evaporator builders in the Lower 48 as well as with UAF Facilities Services, concluding that purchasing a flat steam pan for Northstar Syrup Works' evaporator would be a better approach than attempting to fabricate one. "However," she said, "between the huge demand for custom-made evaporators and the renovations to the power plant coming in the next couple of years, the evaporator project got pushed to the back burner." So instead, she designed and constructed a reverse osmosis unit that costs around $500 with parts that are easily obtainable. This unit was then improved upon by UAF mechanical engineering students Jordan Merkes and Zach Alkire for their senior capstone project. "We increased the efficiency modification for birch sap reverse osmosis," Merkes explained. The machine creates two product streams: purified water and concentrated sap that can be turned into syrup in less time, at less expense, and with greater quality control over the end product, since there is less opportunity to scorch.

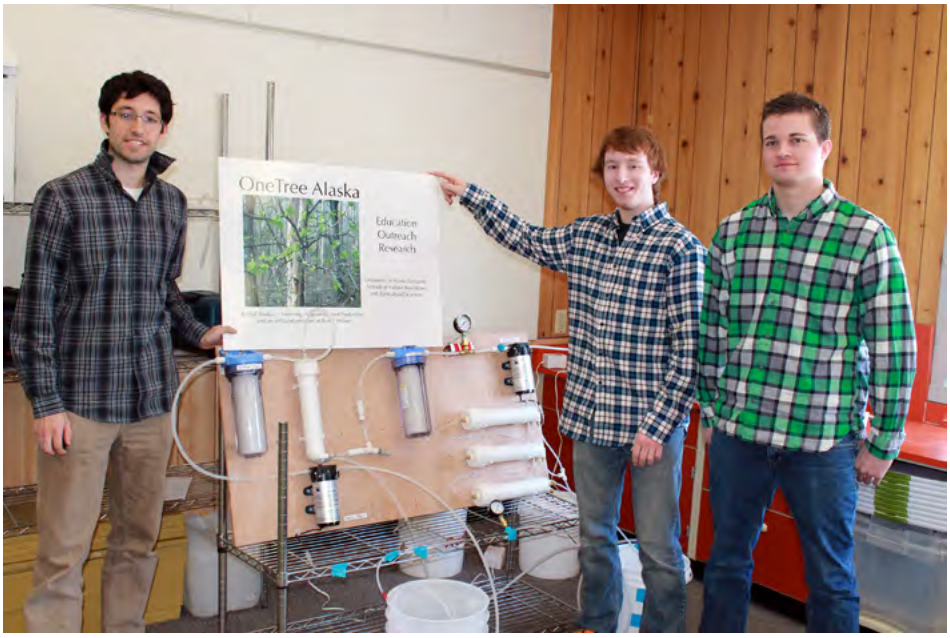
This spring, Dawe and Birch Pavelsky put the reverse osmosis unit through its paces, processing about 20% of the 220 gallons of sap that had been collected by schools and backyard birch sap tappers. The unit handily removed 70% of the water from sap coming straight from the tree, increasing the sugar concentration from 1 brix (1% sugar concentration at 20°C) to 4.5

Tricia Kent, above, demonstrating her initial low-cost reverse osmosis unit. The vertical unit at center is a filter to remove debris; the three horizontal units contain the reverse osmosis membranes. A video showing how it works is available for viewing at http://snras.blogspot.com/2014/01/graduate-student-invents-diy-reverse.html.

—Still image from the video by Jan Dawe

Zachary Meyers, left, and the reverse osmosis machine improved by Jordan Merkes and Zach Alkire, right.

—Photo by Nancy Tarnai



brix. After it was concentrated, Dawe boiled the sap over direct heat for an hour, and finished the syrup slowly over steam.

The reverse osmosis unit needs further testing and refinements. If you would like to be involved with Tapping Into Spring over the summer, please contact Jan Dawe at jcdawe@alaska.edu or call (907) 388-1772.

"Family Matters"

Deirdre Helfferich, Nancy Tarnai, Jan Dawe, Jen McDougall

A growing field of plant investigation, kin recognition, resonates with K–12 students, whose life experience outside of school centers largely on family. "Family Matters" is an experiment that explores this concept. It was initiated by K–20 STEAM Education staff, and embraced by Carri Forbes, seventh-grade science teacher at Tanana Middle School, who used Family Matters as an integrative activity for her five life science classes. The experiment uses progeny from two maternal birch trees from Nenana Ridge, labeled NR5 and NR14, and looks at the interactions between seedlings potted in different configurations. A parallel study was conducted at UAF. The objective of the experiment at both venues is to learn whether growth response differs when sibling seedlings are grown together as opposed to unrelated seedlings grown together. Experiments at other universities, with other species, have shown that some plants recognize and even "help" close relatives.

The experiment was introduced to the seventh-grade science students as an open inquiry investigation, with no expectation of what the results might show. Forbes and STEAM staff emphasized science process skills: the importance of controlling variables (soil, watering, pot shape/volume, size of seedlings) and having an adequate number of replicates in a scientific sample. Attention was also paid during the experimental setup to discussing the limits of the experiment and considering what important information would be missed. For example, only aboveground growth is observed in Family Matters, but other kin recognition studies look principally at root interactions as evidence of cooperation and/or competition between seedlings.

Studying birch trees is one small window onto the world, Dawe said. "But anything that's part of [the children's] natural world could serve the same purpose, salmon or blueberries in rural Alaska, Sitka spruce in southeast Alaska, bird migrations anywhere," she said. "The point is to pay close attention to something accessible in their home environment. If they like working with birch trees, they could become natural resource managers or any kind of field scientist. If they like working in greenhouses they could specialize in plant production. But no matter what career path they take, we're hoping this work helps them become lifelong learners, critical thinkers and good stewards of the environment."

Two pre-service K–12 teachers, Diane Hunt and Jen McDougall (both seeking master's in education degrees), are assisting with the experiment. McDougall describes her experience:

Jan Dawe explained the methods the students should use to take scientific measurements for the Family Matters parallel experiement on their visits to the UAF greenhouses.
—Photo by Nancy Tarnai

> Diane Hunt first introduced me to the One Tree Alaska program last fall after learning that we both had a passion for place-based science education and for the importance of melding of science and art within classroom projects. She invited me to come along as a volunteer to Carri Forbes' seventh-grade class to help introduce the students to birch tree biology. With each class we walked to a schoolyard birch tree stand, Diane read a Robert Frost poem as the students listened and gazed up at the trees, and we helped students root around beneath the trunks to find decomposer organisms that might be found amongst the birch tree leaf litter.
>
> After watching that day unfold and speaking with Diane and Janice Dawe, I was struck by how much impact OneTree Alaska projects could have on science curricula and the educational experience of participating students. The program's thematic and interdisciplinary nature invites teachers to weave boreal forest references within lesson units to make abstract science concepts more tangible and relevant. In an age where young people are often not found playing outside, OneTree projects encourage students

to explore local habitats and gain further appreciation for ecological intricacies and their importance.

…. I have noticed students eagerly wait for "OneTree days." The kinesthetic and artistic elements of the project have helped to draw out engagement from students that are typically harder to reach or struggle in science class. With the Family Matters project, botany becomes exciting for the students as they forge personal connections with the birch trees, and begin to experience the thrills and satisfaction fostered by citizen science participation.

"Exploring Our Environment"

Zachary Meyers

Establishing connections between students and the natural world through art, science, and technology.

Many towns and cities have murals on their buildings, and some buildings even have murals inside. Few have schools with murals created as teaching tools that use interactive features integrated into their curricula—but now Fairbanks is among the first.

The 8' by 40' mural had its nascence in 2011 when the Watershed Charter School librarian at the time asked teacher Ron Harper if his students would be interested in painting a mural in the library. Harper asked second-grade teacher Moira O'Malley, who is an artist, for help. In spring 2013 Laura Cartier, intern teacher, Klara Maisch, local artist, Zachary Meyers, OneTree Alaska instructional designer, and O'Malley met to discuss the possibility of using art to promote multidisciplinary, place-based learning. The group developed ideas for an interactive teaching mural that would be painted with the help of students at the school, as originally envisioned. "Exploring Our Environment" is the result of this community collaboration.

Watershed principal John Carlson was instrumental in gathering curriculum and reference material for the mural. Support from the Fairbanks Arts Association allowed Watershed to hire Maisch through the artists-in-schools program for the initial portion of the project. The BAKLAP program and OneTree funded Meyers to develop the integrated technology for the mural. The Watershed Parent-Teacher Association, the Boreal House Art and Science Center, and Delta Kappa Gamma Theta are also contributors and collaborators to the project. With Cartier, Maisch and Meyers formed the main team working on the mural.

To create the mural, many sketches were developed during the planning stage. The team worked with teachers so that pertinent educational topics and useful examples were represented in the mural, including transportation for second grade, boreal plants for third grade, the salmon life cycle for fourth grade, and fire ecology and Alaska biomass for fifth and sixth grades. The team and Watershed staff (Carlson, O'Malley, Marlene McDermott, and others) worked hard to develop and integrate the content, putting in more than 800 hours, with Meyers concentrating on how the mural would incorporate interactive technology.

After the planning stages were complete, the drawing was prepared and the students' summer art club took on the task of assisting with the actual painting. The younger students blocked in the first layers, and older students added more detail and supplemental paintings. A total of 60 students participated. The painting has taken what felt like a "really sterile" and unfriendly library environment, according to Cartier, and made it "a more welcoming place."

While the mural shines as a beautiful piece of collaborative artwork, its true splendor lies in its hidden ability to serve as a dynamic platform for place-based learning. Through the use of augmented reality, additional layers of content enhance the multidisciplinary, interactive nature of the mural. The images in the mural have reference to both materials in the library and to online information: Using the Aurasma app, Meyers loaded a dozen interactive points throughout the wall with more imagery and details. To use the mural's virtual reality, viewers can download the Aurasma app from Google Play or the App Store on a smartphone or iPad, then open the app and search for Steam Works: Interactive Mural. By following the Steam Works: Interactive Mural channel and previewing the trigger images that are shown on the mural at each interactive point, additional content will pop onto the screen, such as more images, videos, and suggested library books that contain more details. The images on the smartphone device can be double tapped to enlarge them for even more detail. The students' supplemental paintings of boreal animals will be integrated later via augmented reality into the mural's content as more virtual layers are added.

The team carried out several classroom visits to test pilot lesson plans that directly tie keystone concepts with the library's mural content. In McDermott's kindergarten class they used the mural as a platform to talk about leaf shapes and initiated an I Spy game to determine the students' baseline knowledge of local flora. This information is being used to design a supplemental activity this spring. In O'Malley's class the team used the mural to talk briefly about light, shade, and optics. This was followed by a supplemental STEAM optics activity where students demonstrated refraction and reflection phenomena. The activity was so well received by both students and teacher that it is being turned into a lesson plan.

While the mural was under construction, Cartier, Maisch, and Meyers attended the 24th Annual Electronic Visualization and the Arts (EVA) Conference in London July 29–31, 2013. The EVA is an international conference that includes graduate students, museum directors, IT consultants, cognitive scientists, designers, artists, and others. The dynamic and enthusiastic presentation the team gave about "Exploring Our Environment" prompted a lot of excitement in the

audience. Many were particularly struck by the student integration throughout the process of developing the mural. The project was unlike any of the other projects discussed at EVA 2013 because teachers, students, and community members led it. The majority of the talks at EVA focused on academic interests and had substantial capital to support their research. The idea of the project itself was novel through the integration of community, place, and media.

The mural has been successful with the public as well: a First Friday open house in December 2013 saw more than 200 attendees ranging in age from infants to seniors, all of whom interacted with the wall through several iPads that were provided by the School of Natural Resources & Extension. The Watershed PTA provided homemade food and beverages and O'Malley contracted a parent to design a permanent plaque in honor of all who participated. During the event, a looping movie displayed time-lapse shots of the overall process and development of the mural. Student artwork that was created during the summer art club was featured at the open house as well. The two-hour event provided a platform for the students to share their work with friends and family as well as display the power of the true collaborative process. The augmented reality technology mesmerized children and adults alike but it was the wall canvas that stole the show, with its radiating colors and overall cheerful aesthetic.

StoryTelling: A Student's Perspective

Zachary Meyers, Jan Dawe, Nancy Tarnai

This project, supported through the Alaska Experimental Program to Stimulate Competitive Research (EPSCoR) Native Engagement Award, was proposed as a means to provide tools to blend traditional and scientific knowledge of place names, cultural knowledge, and ecological processes through an integrative multidisciplinary STEAM curriculum, using a range of multimedia tools. The hope is that by learning of past, present, and predicted changes, the project will help prepare the current generation to respond to socioeconomic and environmental changes. The goal of this project is to work with a K–12 school, to integrate traditional and scientific knowledge in a way that can be used as a model in schools throughout Alaska rural communities.

Climate change is disrupting many communities in rural Alaska with increased fire frequency, thawing permafrost, reduction in sea ice, large-scale vegetation changes, and shifts in seasonality. Traditional lifestyles cannot keep pace with the rate of change. Each generation faces greater challenges adapting to environmental change while attempting to preserve its cultural identity.

In the past, oral history was the main vehicle for transmitting cultural knowledge. Today, there is a growing body of literature and documentary films—short stories and memoirs

"Exploring Our Environment" and attendees at the December 2013 open house at Watershed Charter School. See detail image on the back cover.
—Photomontage and photos by Zachary Meyers

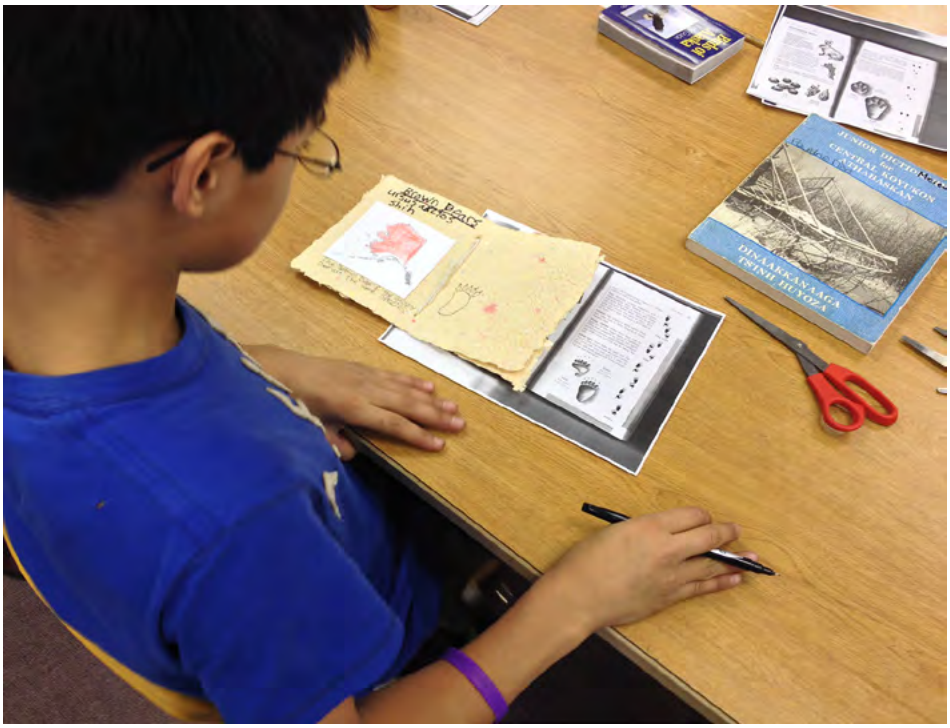
told by Alaska Native elders and storytellers—that act as time capsules for future generations. Many of the traditional stories delve into people's sense of place in relation to the land. These act as great conduits to explore historical environmental change to present and future climatic changes through ecological processes as well as reinforcing the cultural context of the local people.

The melding of technology, art, and science with traditional place-based narratives provides a novel way for students to see their surrounding landscape. By studying a specific site though a story, and documenting the story's cultural, historic, and ecological relevance, participating students gain a deeper appreciation of, and sense of connection to, their local landscape. They also gain skills and knowledge to respond to future changes in ways that reflect local interests and values.

The pilot school used to model the project was Effie Kokrine Early College Charter School in Fairbanks. The teachers were enthusiastic about incorporating elements from a traditional story and having the students explore place-based topics in depth. Throughout the 2013 fall semester eighth-graders from the classrooms of Sheryl Meierotto and Sarah State used art and science to explore local topics in depth (i.e., salmon life cycle, fire ecology, edible plants, and seasonality). With a blend of traditional and scientific knowledge, the lessons helped students apply historical and ecological processes using multimedia tools.

Meyers and Maisch led in the development and implementation of supplemental classroom activities and worked in collaboration with the teachers to reinforce content, creating lesson plans and other materials for teachers that will be hosted on the OneTree Alaska website.

"We introduced exploring story-telling about place as a prelude to a bigger project," Meyers said. The Peirce Park Living Lab Project will create a place near the Effie Kokrine school that will serve as an outdoor living lab for citizen science, offering opportunities to learn and apply science, technology, engineering, math and the arts in a natural setting. (For more about the Peirce Park project, see www.createpeircepark.com.)



Eighth-graders at Effie Kokrine Early College Charter School learned aobut papermaking and created their own journals, exploring local topics and using content to incorporate science and art in a way that honored both literary and oral place-based traditions.
—Photo by Nancy Tarnai

"We wanted to give them a foundation," Meyers said. "This project allowed students to have creative license to explore place and the interconnected relationships among place," Meyers said.

Altered Books and Journals: Honoring literary and oral traditions

The students created altered books in Sheryl Meierotto's class. Altered books are a well-established form of mixed media artwork that changes a book from its original form into a different form by altering its appearance and/or meaning. Students took part in a serious discussion detailing the differences between altering and honoring an original book versus destroying and being disrespectful to it. The project emphasized respect and care for others' work and unique forms of expression. The class was given a choice of topics from their favorite Alaska sport, animal, or season.

The project was intended to focus students on introspective reflections about place through art and science, and to help them communicate their ideas through a creative outlet. Supplemental lessons about story and place were taught in the classroom. For example, students were introduced to Alaska plant taxonomy or dendrochronology (tree rings) and taught how trees illustrate a unique story based on patterns observed in their leaves or the rings of wood. A botanical sketching activity reinforced these principles.

Four activities were directly integrated into each student's altered book. A detailed, reflective narrative describing experiences and knowledge of the student's topic was artistically transcribed into a word path, accompanied by representative objects and imagery. Meierotto's students learned how to write haiku and compose the pieces within their altered books. Three students were chosen to provide audio content by reading their personal

narrative, and all journals were digitized with the three oral narratives overlaid on their own altered book.

The second StoryTelling series that Meyers and Maisch worked on focused on similar themes (sense of place, community, working with raw materials), with Sarah States' eighth-grade class. Meyers and Maisch wanted the students to take ownership of the project from the beginning, so the first STEAM activity with the class was papermaking. The eighth-graders were led through the process of papermaking, learning about pulp, various binding agents, and history. Students were given a choice of warm or cool tones and shown how to manipulate the overall hue of their paper. The students then created handmade journals, using science lessons on dendochronolgy, taxonomy, interpreting animal tracks in the snow, and exploring ecosystem relationships.

The dendrochronology lesson encouraged students to become familiar with tree anatomy, the overall growth process of a typical tree, and how a tree can serve as a proxy for climate records. Samples of tree cross-sections were brought in for a hands-on demonstration. A supplementary lesson was provided to talk about the students' own history in relation to the tree samples (i.e., what year were you born?). An analogue tree cross section was created by the students in their journals to relate anatomy function to relatable items in their own lives. The class was taught basic taxonomic principles (i.e., binomial nomenclature) and history.

Resources were provided to the students so that the scientific name, the English common name, and their Native language name for their chosen animal were integrated into the species profiles. The students created distribution maps with unique facts about each species. Maisch demonstrated making an artistic rendering of an animal track. Students made their own and incorporated them into their journals along with a unique handprint that served as their own "track."

Last, for the literary portion, students were prompted to reflect on what community means to them. The students were given freedom to interpret "community" in both the narrow and the broad sense. The quality of the journals along with the content was high. All journals, like the altered books, were digitized and will be hosted on the OneTree Alaska website, which will serve as a portal to archive these works.

Each lesson utilized science and art curricula to help students explore and express ideas. "This emphasized that there is more than one way to represent and share a story," Meyers said. "We wanted to accommodate a broader sense of place by incorporating observational skills, botanical terminology and introspective thinking."

By working together all semester, the students began to open up to the guest instructors. "It took time to get where we needed to be," Meyers said. "It was a good learning process for both the students and us. We both had to figure out how to share information.

"It was nice to challenge the 'cool factor' that middle school students sometimes have."

Forest Entrepreneur Camp

Nancy Tarnai

The Forest Entrepreneur Camp, or FORENCA, is one of the K–12 programs developed by the BAKLAP K–20 STEAM Education program. Although the original idea was to hold a weekend workshop each month during the school year, this proved too difficult to implement. Instead, the first FORENCA activity was a weeklong intensive camp offered in May 2013.

Chris Pastro at Randy Smith Middle School invited expert craftsman Birch Pavelsky to work with her seventh- and eighth-grade students to manufacture birch knitting needles, chopsticks, and hair chops as a capstone project for the school year. Pavelsky is a longtime professional finish carpenter and woodworker who has worked with OneTree Alaska since its beginning on many projects. A favorite of his has become knitting needle manufacture because it ties together practical knowledge, physics, and entrepreneurship. Pavelsky led students through the needle-manufacturing process, from round logs to finished products. Pastro's classroom was abuzz while students turned birch square stock into needles with the help of a Stanley 77 tenon and dowel maker. Students meticulously smoothed their needles with several grades of sandpaper. Some carved elaborate top decorations. The students chatted excitedly while working.

Before production day, Pastro and the students made predictions about how much material would be lost during manufacture. They took weights and measurements at every step in the process and compared their results to what they had predicted. They tied their needle-manufacturing work to birch germination and growth experiments by sketching birch leaves on watercolor paper. These were fashioned into presentation envelopes to go along with their knitting needles as Mother's Day gifts.

The value of such "maker"activities, as they've come to be called, is that students learn critical making skills. The students in Pastro's classroom learned how to recognize the best types and grain characteristics of wood used in manufacturing different products. They even created business plans for marketing their birch products to two target audiences: tourists at Chena Hot Springs Resort and locals visiting the Tanana Valley Farmers Market.

These forest entrepreneur activities were done against a backdrop of other OneTree Alaska activities completed throughout the winter and spring in Pastro's class, which created opportunities to involve students with different interests and learning styles. Some students excelled at science studies, such as observing the effects of different soils on tree growth, and documenting different life stages, from germination and growth through seedlings' entrance into dormancy. Each student kept a OneTree journal, following a specific protocol known as the Grinnell System of Nature Journaling.

"It's been a wonderful long-term project for these students," Pastro said. "They know more about birch than

Above: Chris Pastro, left, and Birch Pavelsky at her classroom, introducing the students to knitting needle manufacturing. Right: a student trimming the square end of his rownded dowel in preparation for sanding.
—Photos by Nancy Tarnai

a lot of people." She loves that the project incorporates science, math, art, writing, and interpreting data. The fact that OneTree projects are hands-on, and not learned by just reading a book, is another aspect that excites her.

"I want my students to be citizen scientists and observe the natural world," Pastro said. "They are learning to understand the life cycle of birch. It's good for them to slow down and understand something in their back yard and appreciate it."

Having a scientist and graduate students work alongside the children has been inspiring, Pastro said. "It's been invaluable to the students to see someone working in the field and to see that they love their jobs." When the students have the opportunity to work alongside scientists, she said, "They see the possibilities and begin to think they could do that type of work too."

The Importance of Professional Development

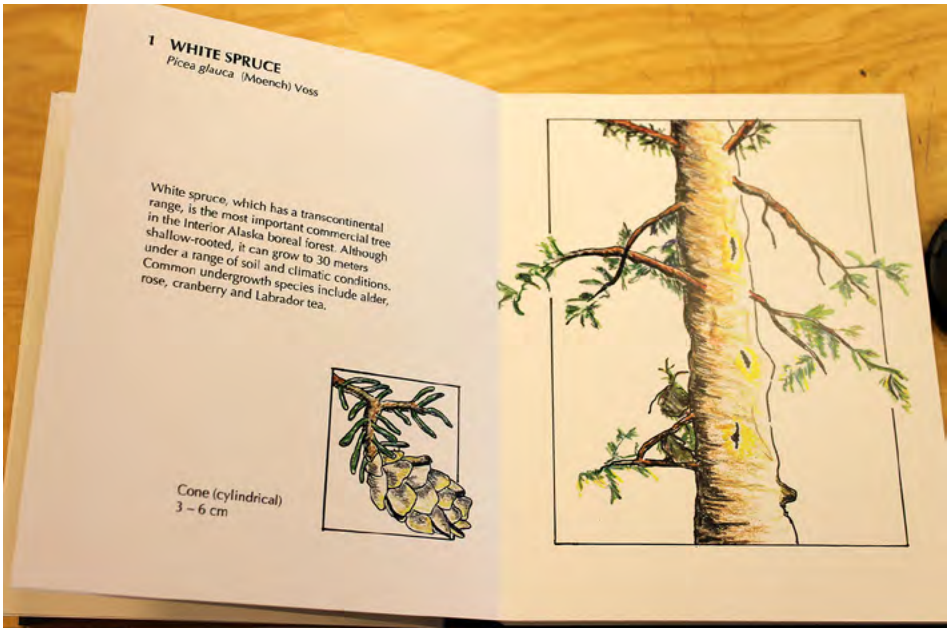
Jan Dawe

Research shows that teacher quality is the most important in-school factor contributing to student academic success, and professional development—the continuous updating of teachers' knowledge, skills, and attitudes—is widely accepted as critical to improving student performance. Professional development begins during the intensive pre-service certification process, and continues throughout a teacher's career. School districts and states determine the minimum number of continuing education credits a teacher needs for recertification.

Even with ongoing commitment to teacher improvement, professional development cannot, by itself, keep the education system on track. In 1983, the Commission on Excellence in Education's report "A Nation at Risk: The Imperative for Educational Reform" chronicled a steady decline in student performance and pointed to the patchiness of the education system's expectations for students as a root cause of the decline. The report called for more coherent national policies: the federal Improving America's Schools Act (1994) and the No Child Left Behind Act (NCLB: 2001) are key pieces of legislation enacted to bring about standards' reform. Thirteen years later, NCLB is credited with both successfully documenting large disparities in learning outcomes between states, and failing to produce the desired result of raising proficiency levels for all.

These failures appear even more glaring when compared against international benchmarks. In 1997 the Organisation for Economic Co-operation and Development began administering international tests every three years to allow countries to compare their students' performance. Results show that the best students in the United States score among the highest-performing international students, whereas the US as a whole ranks below the average for developed countries in reading, science and, especially, mathematics. Our country's concern with falling behind in global competitiveness and the global economy has led both the business and education communities to focus their efforts more keenly on improving teaching and learning outcomes in STEM disciplines. The Common Core State Standards and Next Generation Science Standards can be seen as direct outcomes of this concern.

Developing a teacher-learning community—in which a group of teachers and education leaders continually question



"White Spruce," botanical study number 1 in Trailwalk: July in the Boreal Forest, *resulted from BAKLAP's first professional development course, organized as a STEAM Institute.*
—AFES FILE PHOTO

their practice and together uncover and create new ways to improve—has come to be recognized as one of the most important drivers for raising STEM learning and teaching outcomes at both the national and state level. Collaboration is central to OneTree Alaska and to K–20 STEAM education, but nowhere more than in professional development. One of OneTree's first collaborators, Karen Stomberg, artist and former coordinator of the FNSB school district's Art Center, spearheaded the creation of three statewide Fairbanks Art Institutes designed to be two-week intensive professional development opportunities for K–12 teachers. From these institutes arose eight art curricula kits that are used in the district's elementary schools. "The lessons the art center folks created [in fall 2011] are lovely; good art and good science and very connected to OneTree in philosophy," said Stomberg.

BAKLAP's K–20 STEAM Education program focuses on building teacher-learning communities via two types of K–12 professional development: 1) short-duration, immersive STEAM institutes each summer to acquaint teachers, school staff, and community members with the STEAM approach and 2) stand-alone professional development workshops and courses during the school year to familiarize OneTree Alaska teachers with curriculum content and inquiry protocols to be used in their classrooms.

K–20 STEAM offers its professional development course in partnership with UAF's Summer Sessions and the Boreal House Art and Science Center. The Fairbanks STEAM Institute 2014: "A Botanical Immersion Through Multiple Lenses," for example, was held July 2014 in Fairbanks at West Valley High School. The course is designed for K–12 teachers, artists, scientists, university faculty and students, and community members. Twenty-four participants, including teachers from Fairbanks, Salcha, Central, Eek, and Chugiak, chose field sites in the boreal forest on the UAF campus for inspiration and scientific inquiry. They described, identified, and worked with the plants and insects of their individual plots, and observed interrelationships between organisms and their environment. They made their observations through multiple lenses—i.e. through drawing, data collection, creative writing responses to their plots, and technology. Each contributed a plate of illustrations and writing to an encased portfolio, which was printed and presented to everyone in the institute. Teachers were able to earn four continuing education credits

Participants in the second STEAM Institute, "A Botanical Immersion Through Multiple Lenses," held July 2014. From left to right: Jan Dawe, Chris Pastro, Zach Meyers, Hannah Hill. The 42-inch diameter hula hoop outlines the area of study for each student (in this case Hill) over the two-week period of the institute.
—PHOTO BY NANCY TARNAI

STEAM Institute participants came to know the woods and identify the plants, mosses, mushrooms, lichens, and flowers growing within their hoops. Each student learned biology, writing, and drawing, and created a portfolio with an original piece of their own artwork and copies of their classmates' work. An additional feature was technological: like the mural at Watershed Charter School, each artwork is enhanced digitally with data support on line. The book The Forest Unseen*, by David George Haskell, was reading material for the course.*
—Photo by Nancy Tarnai

for their participation in the course. Six UAF students and one incoming UAA faculty member received full tuition scholarships to attend the Institute, as a form of "forward payment" for service learning projects they'll complete with the K–20 STEAM Education program during the upcoming academic year.

The first STEAM Institute, "Trailwalk: July in the Boreal Forest," was held in 2012. Nineteen teachers participated, and following the production of the limited-edition book a First Friday art exhibit was held in September at the borough's school district central administration office, and featured the contributors' botanical illustrations. The book was so popular, and OneTree and Boreal House Art and Science Center have received so many requests for copies, that it has undergone six reprints.

Laurel Herbeck, North Pole High School art teacher and one of the participants in the 2012 STEAM Institute and the 2013 field drawing class, incorporated what she learned into her classroom practice. She had this to say about the STEAM Institute:

> I would recommend this class to teachers as a way of integrating science, math, engineering, technology and art, as well as a way to challenge students to work the way professional scientists, botanical artists and book designers work. These projects were a form of authentic learning that teaches creativity, problem solving and skill mastery, exactly what we want our students to be able to do as twenty-first-century learners!

Citizen Science and the Generation OneTree Long-Term Ecological Monitoring Plot

Jan Dawe

Citizen science, also called community participation in scientific research, refers to the collection and analysis of long-term data sets by members of the general public in collaboration with professional scientists. One well-known example is the Audubon Society Christmas Bird Count. Each year since 1900, thousands of volunteers take part in making field observations and counting bird visits to backyard feeders during a carefully regulated period. The Christmas count has allowed researchers to gather far more comprehensive data than would have been possible by individual or coordinated professional research teams.

Other citizen science activities, including those coordinated by the National Phenology Network and Project Budburst, record seasonality data such as the arrival and departure of migratory waterfowl, the emergence dates of overwintering insects, and leaf-out and flowering times of target species of trees and forbs. SNRE's professors Elena Sparrow and David Verbyla are primary creators of the Global Learning and Observations to Benefit the Environment (GLOBE) program's Green Up and Green Down protocols, which are used to monitor vegetation phenology and boreal forest disturbances throughout the circumpolar north. Over time, these observations can be expected to greatly aid our understanding of current and potential impacts of climate change on plants and animals.

OneTree Alaska's foray into citizen science came about directly because of community interest in one of our K–12 science experiments. In the 2010–2011 academic year, three classrooms at Watershed Charter School began exploring a climate change-related question with OneTree Alaska. The schoolchildren, their teachers, and university researchers asked: "What are some of the effects of Fairbanks' lengthening growing season on the growth characteristics of Alaska white birch?" To find out how white birch is affected, the students germinated birch seeds, and the resulting seedlings were maintained under thermostatically stable conditions at Watershed School for three-, four-, and five-month growing periods. The same experiment was repeated in a university growth chamber with conditions more closely simulating average Fairbanks growing conditions—including weekly changes in minimum/maximum temperatures. K–12 and university investigators took the same weekly observations, recording seedling height, number of leaves, and seedling branching architecture.

On April 1, 2011, the seedlings were taken out of winter dormancy conditions to become part of the month-long OneTree K–12 exhibit at the Morris Thompson Cultural and Visitors Center in downtown Fairbanks. Dawe and SNRE forestry student Dan Coleman took daily budburst observations on the 144 seedlings in the exhibit. Invariably, visitors to the exhibit stopped by to chat. Although initially

disappointed that they couldn't purchase the research seedlings, they lingered to talk about the growth of birch in their home communities, and landscape changes they'd seen over the years. The seedlings garnered so much interest that the decision was made to keep the collection together.

On June 2, 2011, a 0.3 acre long-term monitoring plot was established in the 'T-field" to continue the collaboration between University of Alaska Fairbanks researchers and public K–12 schools in the Fairbanks North Star Borough School District. Thirty-two Boy Scouts and their leaders from Troop 92 helped plant the seedlings, having learned of the project at an Arbor Day Committee meeting. Dawe and company will gather data at the T-field in the coming years to track how the trees grow. "Then 60 to 100 years from now we will do a second OneTree art and science exhibit from several of the trees we've planted here," said Jesse Hensel, a sculptor and teacher and at the time OneTree's art education lead.

The Generation OneTree Plot is a progeny evaluation trial of eight genotypes from a west-facing Alaska white birch stand (*Betula neoalaskana* Sarg.) located on Nenana Ridge in interior Alaska. Introductory ecology classes at UAF and local K–12 teachers taking summer professional development courses have helped collect data on seedling architecture (summer field sketching courses, for example); UAF graduate students have helped OneTree personnel take monthly productivity observations. "We hope to begin K–12 field trips to the plot this autumn," said Dawe. "If you are interested in helping out in the Generation OneTree Plot, please get in touch!"

Semiotics, Translation, Ecosystems, Assessment, and Metaphor

Jan Dawe, Joan Parker-Webster

America's education system is in a time of rapid change. Federal legislation (The No Child Left Behind Act) and more recent state-driven curricular frameworks based on newly developed Common Core State Standards and Next Generation Science Standards all seek to improve the US education system with a common underlying goal: to provide our nation's youth—no matter where they live—with a high-quality K–12 education that prepares them as lifelong learners who are professionally and personally competent to meet twenty-first century workplace needs and bear the responsibilities of a well-informed citizenry.

Although these three frameworks are drivers of the educational debate in the country today, the decision of whether to adopt or opt out of each one is left to individual states and school districts. Alaska has chosen to opt out of all three in the belief that we can do a better job in-state.

But, as is true with other states, Alaska's educational debate focuses on how exactly to navigate the tension between establishing accountability to authentically assess teaching and learning outcomes and balance the necessity of providing

Service learner and master of education student Hunt (far left) discusses the cold hardiness and dormany experiment with Interior legislators, legislative aides, and university personnel during the legislative field tour September 2013.
—Photo by Nancy Tarnai

individual teachers, schools and districts the autonomy to meet standards according to their own best practices.

How and why does BAKLAP relate to these concerns? On September 20, 2013, BAKLAP provided a field tour and report for Interior legislators to review the progress that had been made during the first year of work. Legislators donned rain boots and vests to visit forest research installations and hear about the project's activities and results, including biomass research and other, non-K–12 related activities. Then they came back to town to meet with OneTree Alaska's personnel, participating K–12 teachers, FNSB School District Central Administration staff, and community experts collaborating with the program. The delegation said they were impressed by what they saw and heard: the integrative approach of STEAM, which has youth make products with boreal forest resources, participate in semester- and year-long inquiry science explorations, and leverage their successes via peer and community service learning opportunities, made intuitive, gut-level sense to the legislators. They liked the STEAM approach, and asked if STEAM's success as an educational philosophy could be documented. More pointedly, they asked if the K–20 STEAM Education program could help legislators and the state define new student and teacher performance assessments.

Assessing the STEAM approach via the OneTree Alaska model was already a deliverable, or product of the BAKLAP grant. The legislators' interest heightened the focus on this part of the project and so OneTree personnel set to work, bringing in both Joan Parker-Webster, formerly with UAF's School of Education, and Diane Noble, who supervises School of Education pre-service teachers. Together they helped design a spring semester course, "Effective Instruction Through OneTree," for OneTree Alaska's core group of teachers to begin functioning as a teacher research group that would help define and implement a pilot project to address three goals:

(a) developing a STEAM-based pedagogy;

(b) further developing and revising OneTree lessons aligned with FNSBSD standards and objectives; and

(c) addressing assessment of student learning gained from OneTree lessons.

The workshop activities were based in the two related frameworks: the STEAM approach and the concept of multiliteracies.

In today's education climate, educational leaders and policy makers are renewing their commitment to the STEM subjects, recognizing these as a driver of innovation with the potential to provide creative solutions to address the global challenges of the next and future generations. However, some educators would argue that STEM alone cannot do the job. What is needed is a STEAM approach, which is the insertion of the arts and design into STEM.

So, what does it mean to turn STEM to STEAM? According to John Maeda (2012), former president of the Rhode Island School of Design (RISD):

> The problem-solving, the fearlessness, and the critical thinking and making skills that I see every day in the RISD studios are the same skills that will keep our country innovating, and their development needs to start in the K–12 schools. Design creates the innovative products and solutions that will propel our economy forward, and artists ask the deep questions about humanity that reveal which way forward actually is. Sustaining arts education in its own right remains critically important. But equally important is taking a page from schools that have been successful at integrating the arts into STEM curriculum (retrieved from www.edutopia.org, June 17, 2014).

Oregon State University post-doctoral scholar Dr. Lissy Goralnik (front row left) met with the 2013 Field Sketching Observation class in the T-field August 1 as a special guest. Her work focuses on the impact of the arts and humanities on the Long-Term Ecological Network sites.
—Photo by Nancy Tarnai

A similar philosophy underlies the concept of multiliteracies, which is predicated on the notion that literacy and literacy practices are always socially situated and ideologically formed. Being citizens in today's social, cultural, and economic worlds, which are technologically dependent and driven, now requires us to negotiate a variety of multimodal texts that utilize a multiplicity of discourses. Such a shift requires a semiotic approach, which means examining how meaning is constructed through all kinds of signs (e.g. drawings, gestures, music, mathematics, dance, movies, etc.), not just the linguistic sign system (reading and writing), which is heavily privileged in school-based education.

Because multiliteracies incorporates multiple sign systems, transmediation—the process of how meaning is constructed and reconstructed as it moves from one sign system to another—provides us a way to frame a pedagogy that has multiliteracies at its core. Multiliteracies, when conceptualized through semiotic representation and transmediation, allows for meaning making across multiple sign systems. Therefore, rather than ask what a child knows, we can ask how many ways are available for this child to know.

This kind of multiliteracies/multimodal and interdisciplinary approach to teaching and learning requires an innovative and appropriate means of assessing how and what students are learning. Consequently the idea that a paper and pencil test alone cannot provide such information is at the crux of the ongoing discussion of the teacher research group involved in the OneTree Alaska Project.

At present this group is involved in collaborative efforts taking place in monthly meetings to align the OneTree lessons with district standards and objectives and begin mapping curricula that include OneTree over the course of the upcoming academic school year. The group is also beginning to develop guidelines for performance assessment based on STEAM and multimodal interpretations of student learning, with science content as a primary objective. It is the goal of the pilot project, which will continue throughout the 2014–2015 academic school year, to develop and field test a set of OneTree lessons and accompanying assessment rubrics.

This is your brain on STEAM

The STEAM integrative philosophy promotes synergy across varying modes of learning. As the many examples above illuminate, a single concept or topic can be explored at depth from different angles, and these enriched experiences allow the learner to retain content longer, think critically about concepts in a metaphorical context, apply knowledge that extends from their learning experiences and make connections to the world outside the academic environment. Physiologically, this has an effect on the neuropathic connections in the brain, which strengthen from repetition and/or looking at a problem from different vantage points. Coupled with the different ways of learning the student is able to establish a robust network of pathways (a "neural network") all relating to a single subject

or topic. It has also been shown that emotional experiences have a pronounced effect on retention, and so all classroom activities incorporate some element of student-driven inquiry learning. This allows the student to take ownership and become vested in the learning experience. The physiology of the brain and what happens while people learn is a large and dynamic field of psychology and education, and full of discovery (in many senses).

BAKLAP and OneTree Alaska have been developing curricula and working with children and teachers since 2009. Just as STEAM engages the child's whole mind and body in active and integrative learning, so too the assessment of learning outcomes should be multi-sensory, comprehensive, and integrative. As new collaborations and projects develop from the foundation that OneTree Alaska and its partners have achieved together, Alaska's students will have a better chance to recognize and bring their strengths, talents, skills, and passions to the world.

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Handmade journal/altered book created by Effie Kokrine Early College Charter School student (see p. 8).
—Photo by Zachary Meyers

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