# KALEIDOSCOPE:

## EDUCATOR VOICES AND PERSPECTIVES

KSTF
Knowles Science
Teaching Foundation

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## ABOUT KSTF

The Knowles Science Teaching Foundation (KSTF) was established by Janet H. and C. Harry Knowles in 1999 to increase the number of high quality high school science and mathematics teachers and ultimately, improve math and science education in the United States. KSTF operates three programs that build national capacity for improving STEM teaching, leading, and learning: Teaching Fellows, Senior Fellows, and Research & Evaluation. To date, KSTF has supported more than 250 Fellows in 42 states.

## IN THIS ISSUE

# WELCOME

Welcome to *Kaleidoscope: Educator Voices and Perspectives.* Just like peering into a kaleidoscope and seeing a range of intricate and colorful reflections, this journal will offer a range of thoughtful and connected perspectives from the multi-faceted areas of teaching and education through the reflections of educators. In an effort to share the knowledge and insight gained through our work in KSTF's unique professional network, the journal will provide substantive and reflective writing informed by our classroom practices and our collaborative inquiry. It is the editorial board's hope to encourage educators to reflect on their own practices, engage in dialogue with other teaching professionals, and empower transformation in teaching and schooling practices.

# INTRODUCTION

This inaugural issue of *Kaleidoscope: Educator Voices and Perspectives* comprises five articles representing a range of experiences, viewpoints, and writing that demonstrates this journal's intention of sharing a variety of voices and perspectives.

Two of the articles in this issue address science curriculum and curriculum in practice. Senior Fellow Zach Powers, along with former student leader Mimi Wilcox, writes about his physics class's engineering project, Team Blend, an international service learning project. Senior Fellow Casey O'Hara explores the potential prospects of interdisciplinary, sustainability-focused, project-based science learning.

Three Fellows—Senior Fellow Mark Hartman, 2010 Teaching Fellow Heather Hotchkiss, and 2012 Teaching Fellow Kate Miller—recount the development, trials, and triumphs of their cross-district International Baccalaureate (IB) Physics collaboration group.

Two authors probe the depths of their practice in self-critical reflection. 2013 Fellow Justine Myers considers the evolution of her beliefs about teacher-student relationships. Senior Fellow Kate Markiewicz shares the deep, practitioner-inquiry process that led her to uncover and acknowledge areas for personal growth as a teacher.

This issue is just our first opportunity to present the voices of current Fellows and experienced educators sharing their perspectives on their classrooms and practices. All of our Fellow contributors deserve our gratitude and respect for bringing their writing forward for us to read, reflect upon, and learn from. We want to thank them, and we are proud to showcase who they are.



The KSTF Journal Editorial Board welcomes all feedback. Please email our editorial board at kstf.journal@kstf.org.

# THE TALE OF A SUCCESSFUL COLLABORATION

## BY MARK HARTMAN, HEATHER HOTCHKISS, AND KATE MILLER


**Mark Hartman** is a KSTF Senior Fellow who teaches physics in North Carolina. He taught students at a variety of high schools in Boston and North Carolina and has worked with other teachers in the KSTF IB Physics group for three years to develop engaging curriculum for students in four different schools.

**Heather Hotchkiss** is a 2010 KSTF Teaching Fellow. She is a physics teacher in Virginia and has been working with the IB Physics group since 2010, along with working with other teachers in her school and district to develop engaging physics lessons.

**Kate Miller** is a 2012 KSTF Teaching Fellow who teaches physics in Virginia. Her attraction to and curiosity about gymnastics fueled her initial interest in physics. Kate hopes to help her students ignite a similar sense of curiosity towards physics as well as develop a love of learning. She has been working with the KSTF IB Physics group since 2012.


At a time when required teacher collaboration is weaving its way into professional responsibilities, we offer a story of a meaningful collaboration that has been maintained for the past three years. With four current members across three school districts in two different states, we work together towards our common goal of helping students learn physics. We have discovered that participating in this kind of high quality group is a sustaining form of professional development, and we believe it has the power to retain quality teachers in the classroom.

We have spent time identifying and thinking deeply about particular practices that we feel would transfer well from our collaboration to various contexts. We hope that by sharing our experiences we will empower others to start or strengthen a collaboration.

### THE BEGINNINGS

Imagine the following scenario:

You are a second year teacher, new to the school and county. You struggled to do labs with students last year. You have students for a two-year course; your incoming seniors had a different teacher for the first year of the course already, and you only vaguely know what he taught them. These are not your only two preps—you have a third course to plan for.

You will have students who are mastering calculus and students who are struggling in geometry. You will have English language learners, and students with individual education plans. You will have students who love science and students who hate science. You will have students who are already overcommitted and stressed to the breaking point, and you will have students who are disengaged from high school and try to avoid contact with peers.

You need to improve International Baccalaureate (IB) Physics scores, because the current passing rate is extremely low. You need to teach physics through inquiry to meet the vision of an IB course. You need to build relationships with and between students so they feel valuable and connected to school.

In 2011, I (Hotchkiss) faced precisely these circumstances. It is a familiar scenario for many teachers: a classroom with a wide range of learning needs across all spectrums, external pressure for students to perform on high stakes testing, internal pressure to "be there" emotionally for each one of your students, multiple courses to prepare for, and all with a general level of inexperience in the

classroom. I wanted teaching to be my career, but I was getting scared because I was rapidly approaching teacher burnout by trying to be a "good teacher" while navigating all of these pressures alone.

That summer, I met Charley Sabatier, Katey Shirey, and Jen Weidman through the Knowles Science Teaching Foundation (KSTF) Teaching Fellowship. We taught at different schools all local to Arlington, Virginia. Jen, like me, was teaching IB Physics for the first time. Charley and Katey had been teaching it for a few years, but always in isolation. We talked excitedly about forming a collaboration, but the concept was very nebulous. Could we bring favorite lesson ideas to share with each other? Could we brainstorm strategies to improve performance on IB lab writing? Could we work on unit tests that model an IB exam?

We arrived at our first meeting cautiously hopeful for a meaningful interaction. At the same time, each of us brought a tangible sense of self-preservation. We were all protective of the time that we would make available to the group, so the conversation was a bit like navigating a budding middle school relationship.

After some negotiation, we tentatively agreed to design and implement our first unit of the year together. Once we decided on this task, one which I was about to sit down and do by myself regardless, I was happy to be a little more liberal with the amount of time I offered for meetings. Our fears were for naught, because once we started planning together, we didn't stop! We continued co-designing and implementing our common units for both the junior and senior level courses all year.

And the results? A higher percentage of my students passed the IB Physics exam than ever had before at my school. I was able to not only '"do labs" but to teach the course through a lens of inquiry, implement opportunities for students to design investigations, and attempt two project-based units. I felt like a much better teacher, and no longer felt on the fast track to burn out.

## CHANGE & PROGRESS

In 2011 we started with a commitment to weekly, hour long, in-person meetings to tackle the "bite size" curricular goal of developing common tests, projects, and keystone lab experiences. This was manageable, and it enabled us to develop a shared philosophy for the course.

Since 2011 our collaboration has grown to be something truly special. Through the years, positions changed causing transitions in membership, until our current group of Mark Hartman (KSTF Senior Fellow), Heather Hotchkiss (KSTF Teaching Fellow), Kate Miller (KSTF Teaching Fellow), and Christine Scott (colleague of Weidman and subsequently Miller) was formed. There are three additional members in the process of joining as this article is being written. We are still bound together by a common commitment to quality teaching and learning. However, our instruction has become progressively more student-centered and differentiated. In the same way, our assessments have become formative, objectives-based, and focused on developing student metacognition.

We continue to meet weekly but do so virtually. Each meeting starts with prioritizing the agenda (which we pre-populate throughout the previous week) and assigning time cues to keep the meeting on track. Typical agenda items include: developing a common storyline for the unit; reviewing a test, worksheet, or lab; and looking at our common assessment results. We have also grown to be able to discuss topics like how to integrate literacy strategies in our lessons and how to scaffold the skills necessary for students to design a rigorous investigation. At the end of each meeting, action items are assigned for the following week using another group determined protocol.

Various forms of technology are used to support the collaboration. Google Hangout serves as the virtual platform for the meeting, Google Documents and Spreadsheets provide a common space for us to contribute in real time, and Dropbox provides a folder structure for organizing our shared instructional materials.

How did we get from point A to point B?

## ARTICULATING NORMS

During the first year, our group developed ways of working together that facilitated a strong collaboration. We decided to try to articulate these as norms in order to share them explicitly with new members joining the group in the summer of 2012.

Our four norms were and still are:

1. We are committed to staying in alignment with each other because it enables our collaborative community to be more powerful.
2. We make decisions by consensus, because of our commitment to alignment, and because it challenges what we take for granted.
3. We are open minded towards the ideas of all group members, respecting that their ideas are as valid as our own.
4. We believe that reflection is critical to growth and supports continuous improvement.

These norms were not decided upon, shared, and then forgotten. They continue to be lived out each week. These "norms in action" have created an environment where different personalities and different opinions can work cohesively towards a common goal.

## NORMS 1 & 2 IN ACTION: LOCKSTEP AND THE STORYLINE

Although the initial plan was to work at the unit level by agreeing on major learning activities and common assessments, it became apparent that we could get more "bang for our buck" if we became even more aligned. When we all taught the same lessons, one hour of work per person meant four hours of product in return. By the end of the first year we had aligned the general sequence of instruction and content of weekly lessons. Now, we are aligned on all daily lessons. Things like designing assignments, thinking through activities and labs, writing tests, etc., are individual action items. We check for quality by reviewing the completed action items as a team.

Most of us are very independent thinkers, so initially the concept of teaching in "lockstep" was unnerving. However, we found that reaching consensus about our vision for the unit ensured that none of us felt we were being told what to teach or how to teach it.

We know when we plan any given unit we all bring a prior storyline to the table, whether it is how we previously taught the material or how we learned it ourselves. We reach consensus by working together to turn our individual storylines into one that is shared. The storyline is not a list of activities nor daily lesson plans, rather it is the cohesive order in which we believe the concepts and skills should be taught to best meet the pre-determined IB standards. For example, in our introductory waves unit we had to decide whether to 1) teach wave characteristics and behaviors first, then spiral back to wave calculations and graphs or 2) teach wave characteristics and behaviors with embedded relevant calculations and graphs.

If you listened to us develop the storyline you would hear phrases like "I wonder about…", "Convince me that…" and "I disagree because…". Discussions can be contentious—an uncomfortable but necessary feeling when our goal is to reach a true consensus about the best way for students to learn the content. In the end, the agreed upon storyline will drive construction of the rest of the unit. It serves as the basis of daily lesson plans and motivates the assignment of relevant and useful action items.

## NORMS 3 & 4 IN ACTION: REFLECTION PROTOCOL

Although we have had successes, we have also had problems. Some of our first issues were our inefficient use of meeting time, the inequitable distribution of work, and the distrust in each other to follow through with quality on the action items. Each of these issues was very real. If they had not been addressed in a timely manner, they had the power to derail our group.

We believe that there will always be conflict when a group of people comes together to work, although the points of contention will evolve with the group. Instead of ignoring the conflict in ours, we try to embrace it as a way to grow and strengthen. Each month, we engage in a "reflection protocol" which creates a safe space to voice concerns about how the collaboration is going.

For our reflection protocol we each write individual responses to a prompt[1], and then silently read each others' responses. After we have read all responses we discuss the patterns we noticed, things that stood out to us, and things we need to change. It is as if the responses are data, and we are pulling out trends from that data. Treating concerns as "data points" disconnects them from the authors, facilitating a greater degree of risk-taking in our conversations.

We believe that the reflection protocol is a powerful place for a new or improving group to start because this will help a collaboration meet the needs of its members. Our ability to overcome the challenges described in the following section resulted largely from implementing this reflection protocol.

## OVERCOMING CHALLENGES

Because we want this story to empower others who are considering or attempting collaboration, we want to be transparent about the fact that this has been a long journey for us. We will end by outlining some of the logistical challenges we had both in adding new members and in building trust. Overall we share the following idea as a guideline: Collaboration is a problem in creative engineering, constrained mostly by the time we can give. That time must be spent carefully to meet the needs of all members, to ensure buy in and, eventually, trust.

Since the beginning we have added five new members (not counting the three that are currently joining). These new members have only sometimes been other KSTF Fellows and have spanned a large range of prior teaching experience. Two of the five chose to leave our group mid-year. We believe we may have asked too much of these teachers too quickly. We are now more careful about spending out-of-meeting time preparing a teacher for the philosophy, the protocols for our group, and the logistics of inquiry style lessons. In addition, we now allow new members to get their sea legs by simply participating in meetings until they articulate that they are comfortable taking on action items. The current challenge for our growing group is learning how to strike a balance between getting new members on board with the existing nature of the collaboration and keeping meeting time sacred and valuable to veterans who want to push to be innovative and metacognitive.

[1]Some examples of reflection prompts include: What's a gold standard professional learning community (PLC)? How are we doing? Where do we want to get to? How do our processes work now? How can we improve to make our collaboration more efficient?

***Because we want this story to empower others who are considering or attempting collaboration, we want to be transparent about the fact that this has been a long journey for us.***

The biggest barrier to developing trust was dealing with the fear that others would not follow through on action items with a high quality product that was "classroom ready." Early on our meetings were inefficient, so we would run out of time to discuss our collective expectations for all action items. We have become more efficient by developing a cycle for curriculum development. For us this cycle is refining our objectives, developing the unit storyline, approving the test, constructing daily lesson plans, and then assigning action items for revising/creating specific curriculum pieces. This process might look different for other collaborations, but we feel having a plan is the place to start. Our focused meetings have created space for in-depth conversations in which we define our expectations for all action items. Over time this has led to increased success with action items, and ultimately to deep professional trust in the group.

## CONCLUSION

We believe that the quality of our shared work is better and allows for more differentiation than anything we could have created on our own. We believe the discussion of the "storyline" for each unit is professionally satisfying and uncovers subtleties in the art of teaching, enabling us to grow our collective pedagogical content knowledge. We believe that the teaching profession must overcome the status quo of accepting isolation in order to make our profession more sustainable and attractive to thoughtful, high quality educators.

In summary, we believe the following to be most transferable to others in a collaboration:

- Reach a consensus on your common vision for instruction.
- Intentionally create a regular time to check in on the health of the group.
- Value the time that you dedicate to the group by allocating it thoughtfully.

We are hopeful that elements of our story will serve as an inspiration for you to bring to your own collaboration context.

## ACKNOWLEDGMENTS

The Knowles Science Teaching Foundation has played an essential role in helping to develop our collaboration.

As KSTF Teaching Fellows we have had opportunities for training in a variety of best practices such as Patterns Approach to Physics, Modelling Physics, Process Oriented Guided Inquiry Learning (POGIL), and Project-Based Learning (PBL) that have influenced our collective teaching style. We also share a commitment to the kinds of professional interaction that formed the core of our norms.

In addition, Sabatier authored several KSTF leadership grants proposals to support:

- Meals at monthly reflection meetings and for summer workshops
- Travel for out of town group member for summer workshops
- A common textbook for us to use as teachers
- Subscription to a shared platform for formative assessments
- Materials to do common labs

Finally, Hartman, Hotchkiss, Miller, and Sabatier have received professional development grants to support their presentation of findings at National Science Teachers Association (NSTA) and American Association of Physics Teachers (AAPT) conferences.

## CITATION

Hartman, M., Hotchkiss, H. & Miller, K. (2014). *The tale of a successful collaboration.* Kaleidoscope: Educator Voices and Perspectives, 1 (1), 3-7.

# TEAM BLEND: CRITICAL PARTNERSHIPS IN STEM-FOCUSED INTERNATIONAL SERVICE LEARNING

## BY ZACH POWERS AND MIMI WILCOX

**Zach Powers,** a KSTF Senior Fellow, is a co-founder and leader of Team Blend, an organization which engages high school students in STEM-focused international service learning projects. He taught physics, chemistry and environmental science for nine years in middle and high schools in and around the San Francisco Bay Area. In 2012, he began working as a school development coach with the New Tech Network, a network of schools using a project-based learning approach around the country.

**Mimi Wilcox** attended high school at Da Vinci Charter Academy, a New Tech Network school in Davis, California. There she was a member and student-leader of Team Blend for two years. She is currently studying Russian and economics at the University of Chicago, and intends to pursue a career in international development.

Photo by Zach Powers

"El Centro Solar" - Home base for Team Blend operations, Sabana Grande, Nicaragua

### BACKGROUND

Nicaragua is the second poorest country in the Western hemisphere, and the community of Sabana Grande is located in the second poorest municipality in Nicaragua. Yet Sabana Grande has become an shining example of what sustainable communities can look like in developing nations. With the help of Grupo Fenix, a Nicaraguan organization dedicated to promoting renewable energy sources in rural communities, they built the capacity of the residents to "research, develop, and apply appropriate, renewable energy technologies."

Davis, California, is the second most educated city in America and the home of Da Vinci Charter Academy, a small, public high school, which is part of the New Tech Network. Students at Da Vinci learn all of their subject matter content, along with key skills like written and oral communication, professionalism, and collaboration, through project-based learning. When science students from Da Vinci partnered with Grupo Fenix and enlisted the help of Peregrine International, a local educational and service-learning non-profit, Team Blend was born.

Now in its fifth year, Team Blend has completed four successful trips to Nicaragua. This is the story of how these three organizations found each other and worked collaboratively to develop and implement STEM-focused international service learning projects. Hopefully, this story can serve to inspire and illuminate the lessons learned for those who hope to engage in similar endeavors.

### PROBLEM IDENTIFICATION

In the fall of 2010, the director of Grupo Fenix, Susan Kinne, arrived in Davis to give a talk at UC Davis. She had been invited by Gwynn Benner of the UC Davis Energy Efficiency Center and Deb Bruns, a local educator and board member of Peregrine International, to discuss potential avenues for collaboration with the community and university. Both Deb and Gwynn had traveled with their families to Sabana Grande to take part in service-learning projects. Susan described the recent construction of an off-grid restaurant in Sabana Grande powered entirely by solar energy. The structure of the restaurant was nearly complete, with solar ovens, efficient wood stoves, and bio-gas stoves to do most of the cooking, but the solar electrical system they had installed was not able to generate and store enough solar electricity to reliably run a blender necessary to make


"Bici-Bomba" - a student designed and built bike-powered water pump

"licuados," blended fruit drinks popular in Nicaragua.

Deb and Gwynn suggested that Susan present the problem to teacher Zach Powers, at Da Vinci. Zach was eager to find meaningful problems for his students to work on, and this new problem fit nicely with the energy efficiency project they were just completing. He was excited to engage his students with an authentic problem that incorporated both physics and engineering-design.

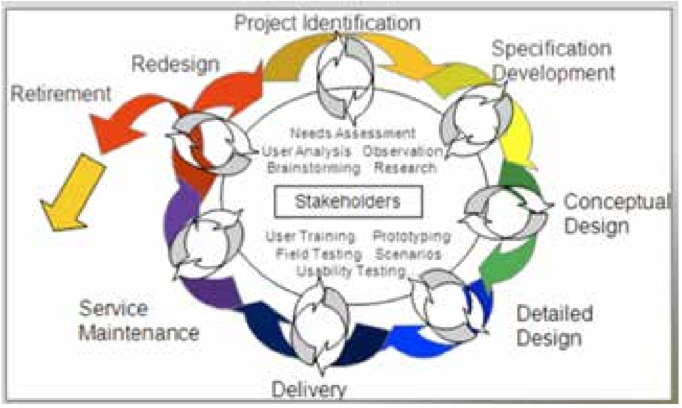
Since the students had already completed their energy project, he presented it as an option to fulfill honors-level project credit or allow regular-level students an opportunity to gain extra credit. To make sure the students understood this was an authentic, real-world situation and not a made-up scenario, Zach invited Susan to come to Da Vinci and present the challenge of the off-the-grid blender to the students, though Zach had no idea what the response would be. He hoped that at least a few students would be interested in spending some time working on the project, but when over 40 kids put their name on the list to be involved, he was struck with both excitement and trepidation. What did he just get himself into?

## ENGINEERING DESIGN CYCLE

Zach now faced the problem that every PBL (project-based learning) teacher loves to have: how does the eager, excited, energy of 40 teens get converted into skills, knowledge, and actual products? Without a framework to guide and focus their efforts, they might spend a lot of time coming up with designs, but have no way to evaluate them, or perhaps worse, jump right into building something without really thinking things through.

Zach used the "Human-Centered Engineering Design Cycle," from "EPICS High," designed by Purdue University, to engage high school students in engineering through service to the community.

Human-Centered Engineering Design Cycle




EPICS High School Workshop, Perdue University

This shows the iterative, cyclical nature of the engineering design cycle which centers around the stakeholders (users) who will be interacting with the product. As the cycle moves from "project identification" through "specification development," the team starts by asking: "what are the needs we are trying to meet?" The question then becomes: "what are the constraints?" and "what does this product need to be able to do?" Students must answer these questions with as much detail as possible, and answers need to be based on what the stakeholders want and how they will use the product (as opposed to how the engineers *think* the users ought to use it). Doing this part of the process well is crucial to creating a product that actually gets used and maintained, as opposed to something that sits and gathers dust.

Once these questions are answered, engineers are able to move into brainstorming conceptual designs. After many designs have been proposed, they use the constraints and specifications to select the most promising design, develop a more detailed design (with associated drawings, measurements, and materials specifications), and finally build a physical prototype, which can be tested and improved before delivering the final product. Ideally, engineers will continue to interact with the users and be involved in evaluating the efficacy of the product as it is used "in the wild." Eventually, the product may either be re-designed or retired. In the next section, you will hear about this process.

## YEAR ONE

The team began meeting weekly in October 2010. In the early stages, students met with Zach at lunch each week to lay out the goals of the project and determine a timeline for the engineering process as well as fundraising and public outreach. The students quickly decided not to merely build a prototype and send it down to Nicaragua or make a how-to video, but to go to Nicaragua to work with members of Grupo Fenix to build blenders in Sabana Grande. The students' early embrace of the human-centered aspect of the design cycle partly influenced this decision. They decided that involving the members of Grupo Fenix in the design and build process would be the only way to ensure that the devices would not end up sitting broken or unused in a corner by allowing the members to take shared ownership of the project. This approach also would build engineering knowledge and skills in the community. The decision to turn a lunch-time science club into an international service learning trip was very much driven and owned by the students. It increased student engagement as well as the scope of what they needed to do.

With this in mind, the students got to work. The first step of the Human-Centered Engineering Design Cycle is to understand the nature of the problem and the stakeholders in order to develop a set of constraints and specifications that will drive the creation of design solutions. Students began brainstorming questions to help them understand the problem. With Zach's guidance, they honed these questions down to a list that would be useful for the design process: Who will be using the blending device? How will it be used? What kinds of foods will be processed? How often will it be used? Does it need to be mobile? If so, what kinds of roads will it travel on? What kind of maintenance might it receive? What kinds of parts, materials, and tools are available in Nicaragua? Will it need to survive outdoors? What building skills do the members of Grupo Fenix already have? After this process the students drafted an email with their list of questions, enlisted their Spanish teacher to help them translate it, and sent it off to Grupo Fenix. Once they had the answers, the group moved forward with a list of constraints and specifications.

| Constraints<br>(what limitations are there?) | Specifications<br>(what does it need to do?) |
|---|---|
| • Built with materials available in/near S.G. (Sabana Grande): mountain bike parts, steel tubing, bolts, and wood<br>• Built with hand-tools, hand-held drills, and a metal grinder only (solar inverter not big enough to run large tools)<br>• No welding in S.G., can be done in a nearby town<br>• All building should done by students and Grupo Fenix members<br>• Relatively cheap to build | • Able to blend: cooked beans, fresh fruit drinks (not ice, no freezer)<br>• Used in an off-grid restaurant, on flat ground, doesn't need to move<br>• Used mainly by short women who wear skirts<br>• Should not take large time or effort to use<br>• Should be easy to maintain (will be done as needed by Grupo Fenix) |

Students formed groups of two to four to research solutions that already existed, and they developed different conceptual designs (rough sketches). Each group presented their designs, which were subjected to a review process strictly focused on assessing how well the proposed design met the constraints and specifications (as opposed to whether students "liked" the design). Some designs seemed promising at first, but quickly fell by the wayside due to the complexity of design or build process, the limited availability of parts, or the price of the parts. For example, one group's design used a set of three inter-meshing gears to get the blender to spin faster. The reviewers decided that this would be costly to get gears like the ones in their design, almost impossible to build them with hand-tools, and almost impossible to replace in Nicaragua if they broke.

***The team quickly decided that the students did not want to just build a prototype and send it down to Nicaragua; they wanted to go to Nicaragua.***

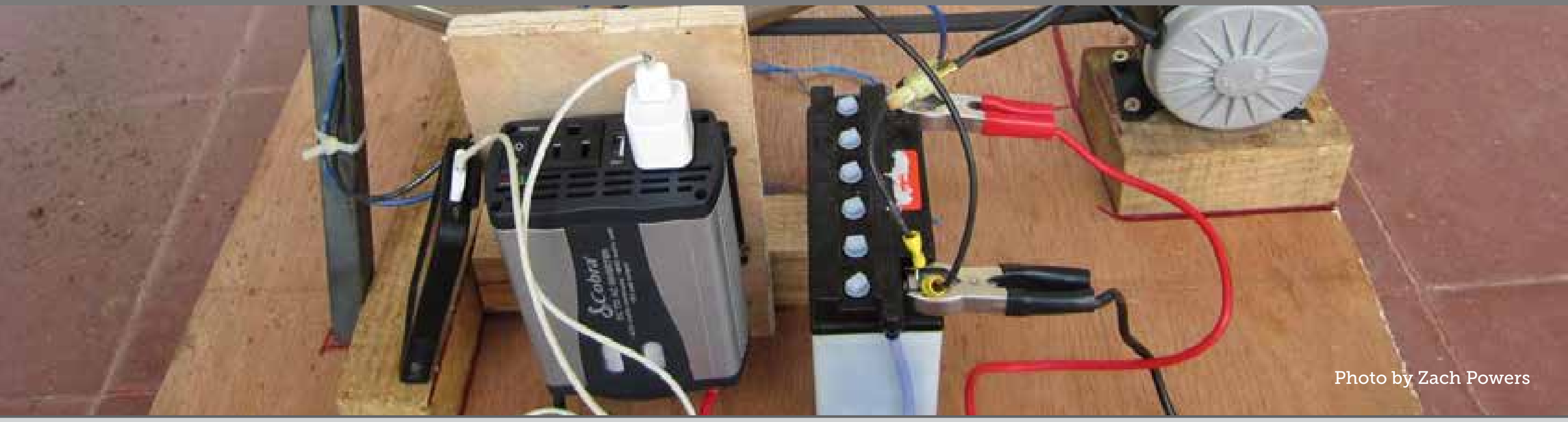


Photo by Zach Powers

"Bici-generadora" - a student designed and built bike-powered generator

It was at this point in the process that something miraculous happened. Students realized that they needed to understand a little more about physics before they could really move on with the design process, and started *asking to be taught physics... after school...with no test coming up!* Zach addressed the students' "need to knows" with an overview of work, energy, and simple machines. The students devoured this new information and put it to work immediately in evaluating designs. When they began asking about gear-ratios, it turned out one of the team members had experience with gearboxes from his work on the robotics team, and he gave a short mini-lesson to the group. To help students get access to real engineering expertise, Zach contacted Jason Moore, an engineering student from UC Davis with experience designing and building human-powered machines. Jason brought in graphs and data tables from kinesiology research to help the team understand how much power a human being could produce for different amounts of time. He also helped them evaluate the relative difficulty associated with fabricating or re-purposing a variety of parts (like bearings, gears, friction wheels, chains, etc.).

Once students felt they had a better grasp on the fundamentals, they were able to more efficiently and confidently decide on a final design, settling on a pedal-powered option that used a friction wheel to drive the blender shaft. High school students from Davis (a city dubbed "The Bicycle Capital of the World") understood and were excited by this technology. They had also learned in their email exchange that the people of Sabana Grande also used bikes on a regular basis and had bikes available to convert.

With help from Jason and Zach, the team created a final design for the blender (complete with dimensions and materials list) and went to work building a prototype. Though few students had any building experience, Zach had enough know-how to give guidance, maintain a safe working environment, and provide access to the basic tools (limited to hand tools, a drill, and a grinder as specified in the constraints) they would need to build the machine.

As the date of their trip drew closer, everyone understood that lunch meetings did not provide enough time. Because some students realized they couldn't make the time commitment, the group eventually stabilized at 25 students. Although initially disappointed, Zach found that working with the smaller, more dedicated group improved the quality of the time they spent together. This committed core decided to meet after school and on weekends each week to translate their design into a physical reality. They cut, drilled, and filed angle iron, tested the frictional properties of different materials, tore apart a few blenders, and tossed around ideas.

Many unanticipated decisions and roadblocks popped up, so the students periodically went back to the drawing board and tweaked the design, all the while conferring with Zach and each other on how to make adjustments when things didn't go as planned or when their original design proved unfeasible. After many meetings and revisions, a first prototype was finally complete. The students engaged in a rigorous testing period (i.e., making delicious smoothies) and some critical feedback sessions followed. Students decided to improve several issues, including the tire selected by the team that was too knobby to maintain constant contact, the mounting of the friction wheel's bearings, and the friction wheel itself which was wearing down too quickly. Students completed a second prototype a few weeks before the scheduled trip.

The team decided to leave these prototypes in Davis, bringing only ideas, experience, knowledge, and a sense of collaboration with them to Nicaragua in order to engage the members of Grupo Fenix in the engineering process.

### THE FIRST TRIP

Along with the engineering process, the team planned and implemented a number of successful fundraising events to buy materials for construction and make their June departure possible. They had decided early on that no one should be excluded from the trip because of an inability to pay, and their dedication to this idea paid off through enthusiastic fundraising. Before they knew it, June had arrived. Eighteen students, along with Zach, Deb and Gwynn, boarded a plane to Nicaragua. Excited, a little nervous, and eager to implement all their ideas, they took off on a 10 day adventure.

The experience that followed was nothing short of life-changing. Students lived with local families, getting to know them and their customs. There was a language barrier, as almost no one in the community spoke English, but Spanish-speaking students were able to help with translation, and those who spoke little Spanish at the beginning of the trip quickly caught on. Students spent mornings at the local elementary school teaching science lessons about sound waves and magnetism and afternoons (after a lunch at the solar restaurant) working tirelessly with two sub-groups of Grupo Fenix to design and build two different bicycle blenders.

The first blender was built by the group of women who run the solar restaurant and had spearheaded learning engineering skills and investigating solar energy in their community. The second was built by a group of local high school students interested in renewable energy and engineering (many of whom were the children of the aforementioned women). By the end of the week, the original design had been improved by the collaborative work in Sabana Grande, and the community was left with two working bicycle blenders: one stationary bike and one portable bike with a fold-up stand. These would be used to make and sell licuados at community events (like Futbol and Baseball games). Nicaraguan students had conceived of this mobile blender just a few days earlier. It required a huge amount of creative design work to pull off a stand that was stable enough to hold the rear wheel of the bike off the ground while being pedaled, but also compact enough to fold up for transport.

Both design teams had many challenges to deal with. Some were fairly clear-cut and just required diligence, like not being able to find parts or losing electricity on a regular basis. But others were a little harder to solve. For instance, many of the Nicaraguan teens, who had little experience with designing or building anything mechanical, felt reticent to share ideas or use tools. It was difficult for members of Team Blend to not step in and fill the void. The team realized that, often, rather than asking in broken Spanish "do you want to drill this hole?" what they really needed to do was put the drill into the hand of their Nicaraguan teammate, smile, and point. Additionally, it quickly became apparent that to make sure both halves of the team were able to stay fully engaged, the Americans needed to speak Spanish whenever possible. When an idea was too complex to share directly, students would immediately get someone to help translate so the Nicaraguan members weren't cut out of the design process.

By the time they left, the members of Team Blend had stepped far out of their comfort zones, immersed themselves in a different culture, faced challenges they never expected, learned an extraordinary amount about the power of collaborative engineering between groups, and built two functional, human-powered blenders.

### EVOLUTION OF TEAM BLEND

In the years which followed the overall process stayed roughly the same, even though the focus of the engineering project changed annually. Each year, starting in October or November, the team engaged in a seven-month engineering process while simultaneously raising funds to make sure all participants could attend. In June, the team traveled to Nicaragua for about two weeks.

Each year the mix of students is a little different. The trip has been opened up to all students at Da Vinci, rather than just physics students, so there is a wider range of ages and a mix of veterans and new members. Bekah Rottenberg, a life science teacher at Da Vinci, replaced Gwynn, who was unable to continue. She added an ecology component which generally involved research and application of sustainable agricultural practices within the community. The team continues to teach science lessons in the local elementary school each year. Engineering projects have included a bicycle powered electricity generator, a blender re-design, a bicycle powered water pump, and most recently a pair of cargo-transport bikes.

On their second journey the students had the opportunity to dive into the last section of the Human Centered Engineering Design Cycle: service, maintenance, and redesign. Though the original project had been focused on electrical power generators, they discovered that after a year of use and abuse both the blenders from the previous year needed some repair and re-thinking. The team decided to split into two groups; while one group worked on the generator project, another worked on the blenders. The previous year of usage had illuminated some short-comings in the design as well as some key places the blenders could be improved. In the stationary bike, they found that the drive-wheel they selected had begun to wobble and lose contact with the friction wheel, and the friction wheel was aligned in a way that unevenly wore down the rubber over time. For the mobile blender, the stand would not stay put when riding on bumpy terrain and needed a better mounting system to be a bit more stable when blending. Both groups got an important lesson in long-term prototype testing and iterative design. By the time the group left, both blenders were running well and much more functional.

During year three, the team built a pedal-driven water pump. Year four included the introduction of a municipal power line and the ability to weld in the workshop area. This opened up new avenues for the design of that year's project—cargo bikes. More importantly, this increased the level of ownership and engagement from the young Nicaraguan engineers, as welding was a skill they were actively learning but the American students didn't possess yet. After four years of engineering experience, some of the Nicaraguan youth are now becoming leaders within their community and posses skills which exceed those of the American students. This has changed the dynamic of the exchange in the last year or two, as there is more equal sharing between the groups.

## STUDENT IMPACT

After returning from a trip to Nicaragua, students almost always speak of their perceptions of the world shifting in some way. For some students, this means becoming more appreciative of their families and the material things they have. This, by itself, is an amazing outcome. However, there are those who also talk about the Team Blend experience as life changing. Some may have joined mainly for the international service aspect, but along the way realized that science and engineering can play a role in improving the world, which helps them develop a love for these disciplines. Others, who might have joined because of the science, have their eyes opened to a country and a way of life they barely knew existed. For many, it is a first chance to be collaborative, creative, adventurous, and to exercise leadership.

After our inaugural year there was a very strong contingent of veteran students who stayed on the team. Some would support the growth of new members in Davis, while a few also participated in a second year of travel. This allowed much of the leadership (both in the logistical and the engineering process) to be assumed by these students. The students who chose to take this on grew immensely from the experience. In the words of a Team Blend member who became a student leader her second year on the team:

> There are not many programs offered in high school that emphasize collaboration in an international context the way that Team Blend does. I think it was quite a unique opportunity for me to be able to assume a leadership role in a peer group doing such important work. Being a leader pushed me to invest in the project in an even more serious way and strengthened a skill set that I frequently rely on in college. Because of my prior experience with Team Blend I was much more inclined to seek out similar leadership roles when I started as an undergrad. Thus far, I have been able to draw on my experiences with Team Blend in every one of those roles. I am currently participating in a year long study abroad program with other students from my university and I feel very strongly that my decision to apply was heavily influenced by my experiences with Team Blend.

## CONCLUSION

The students in Team Blend learned about collaboration, communication, travel and other cultures, but their entire project was focused around


FOR MORE INFORMATION, OR TO GET INVOLVED WITH TEAM BLEND, PLEASE CHECK OUT OUR WEBSITE AT HTTP://TEAMBLEND.ORG.

STEM. By building the bicycle-powered blenders, generator, pump, and cargo bikes, students met STEM standards by learning about torque, gear ratios, simple machines, friction, geometry, electricity, efficiency, fluid dynamics, and the engineering design process.

Since the first year of implementation, many aspects have been tweaked, added, removed or improved, yet the core mission of the group has remained the same: to engage the members of Team Blend and their Nicaraguan partners in authentic, collaborative, meaningful engineering projects that have real-world value to people. Both groups have recognized the tremendous educational value provided by this opportunity and, true to the Human-Centered Engineering Design Cycle, are very conscious to gather and reflect on the experiences of all the stakeholders so that they might iteratively improve the process and outcomes for everyone.

**REFERENCES:**

EPICS High School: http://ow.ly/FnFJh

Zoltowski, C. (2012). *Introduction to human-centered design* [PowerPoint slides]. Retrieved from http://ow.ly/FxuMg

**CITATION**

Powers, Z. & Wilcox, M. (2014). *Team blend: critical partnerships in STEM-focused international service learning.* Kaleidoscope: Educator Voices and Perspectives, 1 (1), 8-14.

# WORMS, BUNNY-HUGGERS, AND THE TRIPLE BOTTOM LINE: MULTIDISCIPLINARY PROJECTS FOR ENVIRONMENTAL EDUCATION

## BY CASEY O'HARA

**Casey O'Hara** is a KSTF Senior Fellow. For eight years, he taught physics, integrated science, and engineering & green technology at Carlmont High School in Belmont, California. In 2014, he completed a Master of Environmental Science and Management at University of California, Santa Barbara's Bren School and an American Association for the Advancement of Science (AAAS) Mass Media Science & Engineering Fellowship at *The Oregonian*, in Portland, Oregon. Following completion of his AAAS Fellowship, he is planning to research marine energy resources and ocean conservation.

*You will die but the carbon will not; its career does not end with you. It will return to the soil, and there a plant may take it up again in time, sending it once more on a cycle of plant and animal life.*

*-Jacob Bronowski,*
*mathematician, biologist, historian of science, poet*

Kai (a pseudonym) held out her hands at exactly the right distance to balance squeamishness and curiosity, peering cautiously into a squirming ball of earthworms. Awkwardly, she dropped the worms back into their worm bin and listened as the guest speaker explained the finer points of vermicomposting to the whole group of middle school students from Honolulu's School for Examining Essential Questions of Sustainability (SEEQS). Kai and her classmates were enjoying a tour of Kapiolani Community College's Culinary Arts facilities, having just come from watching the tilapia lazily swimming in the aquaponics tank, shaded by lush passion fruit vines. The water flowed over beds of crushed lava rock, as bushy green stands of basil, chard, cilantro, and kale filtered the fish waste out of the water to use as nutrients. A solar-powered pump returned the newly cleaned water back to the fish in a continuous burbling cycle.

"Sustainability is the lens we chose for this school," explains school founder Buffy Cushman-Patz, "because it is such a pressing issue that this generation of students is going to have to solve."

Each semester, the school's faculty discusses, debates, and decides on an Essential Question of Sustainability that captures some fundamental issue related to sustainable living. "How does water sustain us? How does the way we get around affect where we live? How do government and economic systems affect culture and resources? What role does the ocean serve in regulating life on earth? What does it mean to live well on an island?" Cushman-Patz leans forward, a furrowed brow replacing her relaxed Hawaiian demeanor. "There are all kinds of essential questions adults think about in real life, and we want students to be digging into those questions." Each day, the students spend the mornings learning the traditional academic core—science, history, English, math. But every afternoon, the students are given the freedom to choose their own interest within the larger Essential Question of the semester.

This semester's Essential Question: "What do we eat, and why?" Some students may choose to study the fascinating history of foods


SEEQS students explore an organic garden to observe and practice sustainable food production

important in Hawaiian culture; others may choose to build and maintain a small organic garden plot on the school grounds. Some, like Kai, may close the loop by maintaining a worm bin of their own to turn food waste back into nutrients for the soil.

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This phrase, from the 1987 report from the UN-established World Commission on Environment and Development, is frequently cited as the earliest operational definition of sustainability.

At its most fundamental level, sustainability dictates a balance between rates of consumption and renewal of a resource. Use water faster than it is being replenished, and go thirsty. Harvest fish from the sea faster than they are capable of reproducing their population, and go hungry. And emit more carbon dioxide to the atmosphere beyond the earth system's capacity to absorb the excess, then watch unpredictable changes in the planet's climate.

As Kai investigates how worms turn vegetable scraps into worm castings—worshipped by gardeners as "black gold"—she will need to be able to navigate the human-imposed boundaries between physics, chemistry, biology, and earth science. Too often, these artificial silos of scientific knowledge are taught in isolation, obscuring the complex interactions that weave nature's grand symphony. Kai will need to understand the progress of energy, water and carbon through the microcosm of the worm bin—from the leftovers of the vegetable harvest, to worm castings, to the soil, to the plant, to harvest, and closing the loop back to vegetable scraps. If her project is successful, Kai will feel the warm glow of success in keeping her tiny charges alive. If for some reason her herd of red wigglers does not survive, she will learn an even more poignant lesson about the pitfalls of human-managed ecosystems. In that case she clearly must have missed some influential variable, too much of one thing or not enough of another, disrupting the cycle's delicate balance. When it comes to robust learning, nothing succeeds like failure.

Challenging students to face complex problems was a foundational philosophy for Cushman-Patz as she designed the School for Examining Essential Questions of Sustainability, conveniently abbreviated as SEEQS. "There is no concept of sustainability for which the solution doesn't require interdisciplinary thinking." And yet standalone science courses tend to be the rule in U.S. high schools; interdisciplinary science courses are the exception.

California offers a potentially instructive example of the dearth of interdisciplinary sciences. At the high school level, the state offers standards and tests for each of the standalone sciences, each an isolated movement of Nature's complex symphony. In addition, California has created not one, but four levels of integrated science standards, "remixed" from the standalones, but with no apparent effort at framing a coherent melody line to provide necessary context. In 2013, some 1.2 million California high school students took standardized tests in science.[1] Yet fewer than one in 25 of these students were tested in an integrated science. Trends in the past 10 years show participation in integrated sciences decreasing, even as overall science enrollment increases rapidly.

Of the students tested in one of the standalone sciences, nearly half achieved a "proficient" or "advanced" score, the targets set by the state. Of the

[1]California Department of Education (2014). 2013 STAR Test Results, California STAR Program. Retrieved from http://star.cde.ca.gov/star2013/index.aspx

students tested in an integrated science, only one in four demonstrated the same level of proficiency. This poor student performance almost certainly reflects the populations of students and teachers: all too frequently, integrated science courses are offered as remedial science for the lowest-performing students; and all too frequently, these courses are thrust upon the newest teachers, with the least preparation and experience. This poor student performance may also reflect the difficulty of teaching such a class; even an experienced teacher might struggle with the depth of content knowledge needed to connect the disparate topics into a coherent storyline.

*That land is a community is the basic concept of ecology, but that land is to be loved and respected is an extension of ethics.*

*- Aldo Leopold, author, ecologist*

At six foot four, sporting cop shades and aggressive muttonchop sideburns, KSTF Senior Fellow and biology teacher Jim Lane bears little resemblance to the "hippie bunny hugger" he has sometimes been called. Mirrored eyes suggest Strother Martin in Cool Hand Luke, as Lane surveys his students laboring like a chain gang in a large open field beneath the midday sun. He would be an intimidating figure but for his loud laugh and goofy sense of humor. And these kids are enthusiastic participants in Lane's high school environmental science class. Where his students have yet to work, the field looks like a featureless monoculture of Kentucky bluegrass lawn, but in the wake of his students' progress, the field is dotted with a haphazard pattern of shallow holes filled with seedlings diverse in leaf, stem, and flower.

Inspecting the plantings, Lane seems pleased. Inspired by Aldo Leopold's concept of the Land Ethic, Lane and his class had decided to restore this half-acre field to its natural state, recreating a critical habitat that used to typify Minnesota's prairie. The restored field would serve as a living laboratory, demonstrating how low maintenance landscaping can improve habitat for native pollinators, birds, and insects.

*Andropogon gerardii, Bouteloua curtipendula, Bouteloua hirsuta, Bromus ciliatus, Carex alopecoidea, Eragrostis spectabilis, Schoenoplectus fluviatilis:* these are just a few of the native prairie plants and grasses that Lane's class will replace. These plants provide food and shelter for animals, birds, and pollinating insects. They provide structure under the weight of snowfall to provide areas for spring nesting. The roots of these prairie plants provide erosion control during the strong rains and winds of late spring and early summer, and dig deep into the soil for water access during the dry months to provide excellent food supplies for herbivores. Prairie biodiversity improves the ability of the soil to retain water and nutrients, and to hold on to carbon in the form of organic matter, all of which help maintain the health and abundance of the interconnected species.

In short, the restored prairie represents a self-sustaining ecosystem—one that used to cover large swaths of the country, but has been largely mown down to make room for human development.

"Sustainability is a word that has been grossly overused in recent years," says Lane. "From a human perspective we have been growing exponentially as if the resources truly are infinite." Fossil fuel consumption drives controversial extraction techniques such as fracking and mountaintop removal. Demand for biofuels and livestock feed drive deforestation to make room for corn and sugar cane. Barely restrained fishing pressure drives once plentiful marine populations to the brink of extinction. "We want it all but we don't want to sacrifice anything to ensure the future of our species on our planet."

The Kentucky bluegrass field that Lane's students are replacing is an entirely artificial construct, unfamiliar in the grand history of the American plains. Ten thousand years ago, as the ice sheets retreated from Minnesota's surface after the last ice age, the freshly exposed virgin soil developed a complex prairie ecosystem of grasses, shrubs, insects, microbes, animals, birds, and predators. Human development in the last hundred years has essentially eradicated the prairie ecosystem in favor of weed-free lawns, carefully groomed public parks, intensively grazed pastures, and vast acres of single-crop agriculture. Irrigation, fertilization, and flood control have fundamentally altered the flow of water and nutrients to, from, and within the ecosystem.

All these modifications have been made in the name of improving the human condition: more food and less hardship. This ostensible convenience comes with consequences. Some are easily understood at the time of tradeoff, for example every row of corn planted means one row of soybeans that cannot be planted. Other tradeoffs have only recently begun to be appreciated. Loss of biodiversity decreases the ecosystem's ability to resist drought, disease, and fire. Replacing soil nutrients with man-made proxies kills the natural soil ecosystem of bacteria, fungi, and countless creepy crawlies who continually replenish the topsoil for future generations. A vicious cycle begins, in which additional artificial fertilizer must be used every season to make up for the murdered soil. Excessive use of artificial fertilizer increases nitrogen and phosphorus runoff to streams and rivers, creating algae blooms that deplete the water of oxygen and create dead zones downstream.

*The 'control of nature' is a phrase conceived in arrogance, born of the Neanderthal age of biology and philosophy, when it was supposed that nature exists for the convenience of man.*

*-Rachel Carson,*
*marine biologist, conservationist*

In order to properly restore this half-acre patch of ground to a sustainable ecosystem, Lane's students had to explore far beyond the bounds of a typical biology textbook. To determine appropriate plants for the restored prairie plot, students researched the sunlight, rainfall, temperature, and soil geology—introducing ideas inherent in physics, chemistry, and earth science. "In doing the project they were required to understand many other aspects of environmental science that are often taught as independent topics," explains Lane. "The project serves as the context in which the major content ideas are grounded."

Projects in the classroom are nothing new. John Dewey, a principal figure in the early progressive education movement, espoused the benefits of "learning by doing" in the waning years of the 19th century. Progressive and constructivist educators have since relied on authentic projects to provide context for student learning. In the past decade, through the efforts of organizations such as the Buck Institute of Education and high-profile charter school groups such as the New Tech Network and High Tech High, formalized "project-based learning" has become an educational buzzword. But the fundamental concept is still the same: Learning by doing.

As the day winds down, Lane's students are doing. Back in the classroom, several clusters of students work on aspects of the prairie project—perusing seed catalogs to prepare for the next round of plantings, contacting local greenhouse professionals to mine their expertise, and setting up fundraising events to engage with the community.

A well-designed project creates an intrinsic need-to-know, an interest that drives students to explore and learn for their own sake. Lane's students will not face a multiple-choice test about the prairie project. Grades are not the motivator, but rather curiosity and the desire to make a long-term investment in the health of their natural community. Students are enabled to prioritize their objectives, to write in leaf and soil their ecological values. Nature itself becomes the test—does their "restored" ecosystem pass muster of temperature, rainfall, and soil health?

Every interaction between humans and the environment brings with it multiple consequences, many unintended, others unforeseen, and still others that lurk undetected. As with Kai and her worms, a broader understanding of the interconnections between the scientific disciplines helps illuminate the possible consequences much more brightly than the piecemeal approach to science typical to many schools. Interdisciplinary science informs the theory, and real-world projects provide an avenue for students to explore, reflect upon, and apply that understanding in context.

"Teaching for sustainability means putting students into real-world situations that require them to think critically," explains Cushman-Patz. "It takes more than teaching 'critical thinking skills' in the abstract.

***"I get my kids outside and try to get them connected to the natural world around them," says Lane. How can they be inspired to save the planet if they don't even know, or care about, their own backyard?"***


Photo by Casey O'Hara

We're asking them to think about the consequences right now."

*It is horrifying that we have to fight our own government to save the environment.*
*-Ansel Adams, photographer*

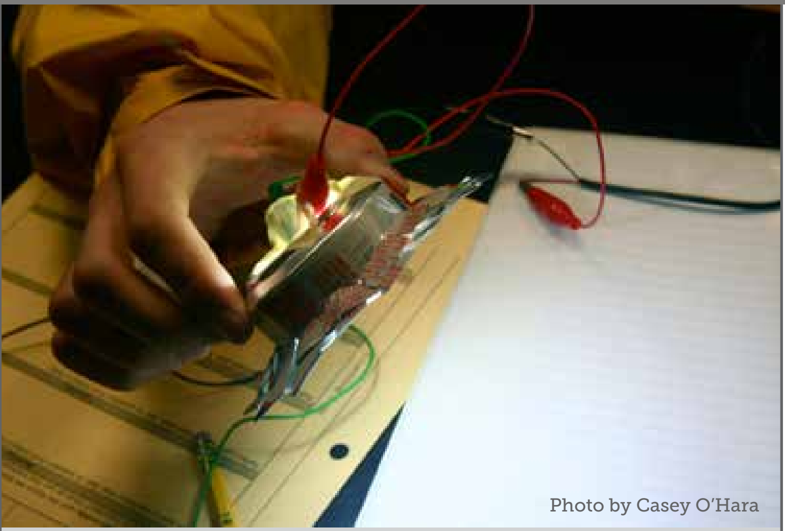
If interdisciplinary project-based learning is such an effective path to learning, why are these examples not the norm in classrooms across the country?

Any educator is familiar with the systemic inertia that resists change. Standardized testing, mandated by state and federal education policy, puts pressure on teachers to at least superficially address every one of the disparate state-mandated standards. Many states are moving toward student test scores as a means of evaluating a teacher's performance. Political pressure from parents and school and district administration discourages innovation by all but the most secure or most adventurous educators. This onslaught of pressures leaves teachers little to no time to implement interdisciplinary projects. Narrowly focused standards leave little room for exploring the connections to other scientific disciplines.

"It's frustrating because sometimes decisions are made so far away from the classroom experience that by the time the rules get trickled down here," Cushman-Patz sweeps downward with her hands, "it's not what's best for students." This frustration drove her from own classroom in pursuit of a better solution. She studied School Leadership and School Development at the Harvard Graduate School of Education, earned her principal's license, and founded SEEQS in 2013.

Political ideologies set up additional obstacles. "The biggest challenge that I have faced," claims Lane, "is resistance to the 'liberal agenda' that is often perceived to exist in the content of many environmental issues." Liberal politicians are often pilloried for environmental views: Jimmy Carter for urging people to put on a sweater to conserve energy; Al Gore for his film "An Inconvenient Truth" and his work with the Intergovernmental Panel on Climate Change. In his 2012 presidential campaign, Barack Obama's opponents mocked his concern for sea level rise and climate change. Conservative politicians actively deny scientific evidence of climate change: "the greatest hoax ever perpetrated on the American people," according to James Inhofe, Republican Senator of Oklahoma. By immersing his students in the environmental experience rather than the words, Lane hopes to circumvent the divisiveness of hippie bunny-hugger politics. "My goal is to make conservation and environmental issues seem more common sense than the politically skewed versions that we see in the media."

Is the role of education to raise awareness and knowledge about environmental problems, allowing students to inform their own choices? Or should educators teach students to take action by promoting specific behavior changes and activities? This tension is evident in the report from the first United Nations Intergovernmental Conference on Environmental Education, called the Tblisi Declaration after the host city. The Tblisi Declaration outlined goals and objectives for environmental education, to provide guidance to nations developing environmental education programs. The declaration's first two goals promote awareness and knowledge of environmental issues—crucial and undisputed aspects of environmental education. The third goal, however, suggests advocacy: "to create



A carefully woven aluminum can provides the housing for a prototype LED light fixture

new patterns of behavior of individuals, groups, and society as a whole towards the environment."

Awareness and knowledge alone can change attitudes and influence behaviors. But many teachers stop short of actively encouraging specific changes in behavior, to avoid administrative and ideological controversy. Picture a classroom in which students study worm bins, but are not encouraged to practice vermicomposting in the larger context of food waste and organic farming. Picture a classroom in which students study the workings of a prairie ecosystem, but are not encouraged to engage with their local community to recreate such a prairie on their own school grounds. But as scientific research reveals the magnitude of environmental challenges we face as a nation and as a species, will awareness and knowledge alone be enough?

*We need to defend the interests of those whom we've never met and never will.*

*-Jeffrey D. Sachs, economist*

The classroom is in a state of mild disarray. Each group of high school students surrounds a table covered with bits of plastic and wood, solar cells and scavenged cell phone chargers, tools and sketches. Aryn, Byron, and Ryan are testing how changes in voltage affect the current and brightness of an LED. Andy, Sam, and Zach are manipulating a plastic coke bottle to focus light from their own LED onto a light meter. Sammi, Mackenzie, and Connor are intricately weaving strips from a reclaimed soda can to make a tiny attractive lampshade for their own design. The students are designing low-cost light fixtures that can be powered by solar-charged batteries, to replace the kerosene lamps commonly used in many parts of the developing world. The project was inspired by John Barrie, founder of the Appropriate Technology Collaborative (ATC), which runs a workshop in the poor rural highlands of Guatemala to design affordable and clean technology that can be made and marketed locally. The classroom was my own, and this project in my Engineering & Green Technology course was my effort to actively engage students in social, economic, and environmental sustainability at a grassroots level.

When I approached Barrie about doing a project with his organization, he quoted a portion of the ATC's mission: "Market-based solutions that are culturally sensitive, environmentally responsible and locally repairable in order to improve the quality of life and reduce adverse impacts on the environment." First and foremost is empowering people and promoting dignity in low-income countries. "Poor people don't want cheap looking things," explained Barrie. "Sometimes we have seen well-intentioned nonprofits cut a Coke can in half and place an LED inside. They then nail the light to a person's ceiling. Not attractive. We try to encourage students to design lights that look like what you would want in your own home."

By the end of the project, some of my students had repurposed plastic scraps into products that would not look out of place in any home improvement store. And while other groups had crafted functional lights that might not pass the "what you would want in your own home" test, every student had been actively engaged in the science, the culture, and the economics of sustainable design. I was very proud of what my students had accomplished in such a short time.

One year later, I had left the classroom indefinitely.

*Why are ecologists and environmentalists so feared and hated? This is because in part what they have to say is new to the general public, and the new is always alarming.*

*- Garrett Hardin, ecologist*

I had worked for years to build up the classroom capital to create my own course, wrangled grants and awards to help fund the projects, and created an atmosphere where students were empowered to explore sustainability outside the bounds of standardized testing. But a question still nagged at me. My students, and those of Cushman-Patz and Lane and many other fantastic teachers in other parts of the country, are achieving the stated objectives of the Tblisi Declaration—awareness, knowledge, and action with respect to environmental issues. The basic scientific underpinnings of sustainability are understood by all but the most intractable of climate-change deniers. So why, despite this understanding, are we as a nation and as a species, still rapidly depleting our valuable resources and polluting our precious planet?

"It's not just a science question, it's also a question about the way people and self-interest and collective benefits interact with each other." Steve Gaines speaks as much with his hands as with his voice. Gaines earns a sense of authority as much from his crisp enunciation and neatly-trimmed salt-and-pepper goatee as he does from his title: dean of the Bren School of Environmental Science and Management at the University of California, Santa Barbara.

Environmental management is fundamentally about human management. Human institutions manipulate our natural resources to meet our physical, cultural, and emotional needs. Human beings are not entirely irrational in their behavior; they generally act in what they perceive as their own best interest. An understanding of environmental issues requires an understanding of the incentives that drive human behavior.

"If you want to teach sustainability," Gaines emphasizes, "you have to teach economics." And this is why I left the classroom: to immerse myself in the Bren School, to further my own understanding of environmental economics, policy, law, and science. Environmental philosophers and ethicists have proposed many variations on the role of humans with respect to the resources of the Earth. Some argue that the resources were placed, by God or by chance, to be exploited by individuals for fun and profit. Others argue that the bounty of nature belongs to the human race as a whole. Still others argue that nature bears its own inherent rights, and that humans must act as stewards to preserve nature for future generations. The current reality, however, pays little heed to environmental philosophy, and instead follows the economic philosophy of capitalism to drive action.

A foundational concept of resource economics is commonly known as "Tragedy of the Commons," based on an influential essay by ecologist Garrett Hardin. Hardin's essay described a scenario in which a number of herdsmen graze their cattle on a public pasture, or "commons." The pasture, while limited, is plentiful enough to sustain a certain number of cattle indefinitely. However, a rational herdsman will realize that by adding an extra cow to his herd, he will gain all profit from the additional sale, while the harm caused by the additional cow's grazing is shared equally among all the herdsmen. The herdsman sees an incentive to continue adding cattle to his herd; the other herdsmen reach the same conclusion. Quickly the cattle population increases beyond the capacity of the pasture to feed them. Soon, the pasture is a barren wasteland, the cows are starving, and the herdsmen are out of business.

The plight of cattle and herdsmen wasn't Hardin's main concern. His allegory is a lesson that can be applied to any publicly available resource. One of the clearest examples of tragedy of the commons can be seen in the collapse of historical fishing grounds. Unrestricted fishing pressure caused the collapse of Pacific sardines in the 1950s and Atlantic cod in the 1990s, and overfishing currently threatens 85 percent of species worldwide, including the Atlantic bluefin tuna and the Patagonian toothfish (more appetizingly re-marketed as Chilean sea bass).[2] "Self-interest is a gigantic motivator," explains Gaines. "Unsustainable practices offer an opportunity for people to succeed as individuals at the expense of others."

It is a fact of life that our global economy is driven by financial considerations. This includes our interactions with our environment, the reaping of natural resources, all too frequently for short-term gain without regard to long-term consequences. Considering economics in environmental policy is seen as the key by most economists, frequently by creating "property rights" for otherwise public resources. To prevent overfishing, a limited number of "catch shares" allow individual fishermen to harvest

[2]UN FAO (2010). The State of World Fisheries and Aquaculture 2010. Rome: FAO.

a certain amount of fish, while the overall harvest is limited to a level that allows the fish population to recover fully each year. To rein in pollution from fossil fuel power plants, "cap and trade" policies establish an "allowable" amount of pollution (the "cap"), and power plants must purchase shares to allow them to pollute (the "trade"). Over time, the "cap" is lowered, increasing the value of the remaining credits; the increasing price creates an economic incentive for power plants to invest in cleaner technologies.

While the finer details of environmental economics may be beyond the reach of most high schoolers, the basic concepts of public vs. private goods, exclusive vs. open access, and supply vs. demand are already taught many high school economics courses. Economics taught in the abstract ("widgets," anyone?) or in isolation, however, does little to further student understanding of sustainability, any more than physics taught in the abstract or biology taught in isolation. In fact, says Gaines, "A lot of people think economics is the problem, but that's because they don't understand that economics is not just how do you maximize profitability. Economics is all about understanding what are the incentives, what are the motivators of behavior. By understanding those things, you may make better choices." Empowering students to make better choices—isn't that a fundamental goal of environmental education?

*The great challenge of the twenty-first century is to raise people everywhere to a decent standard of living while preserving as much of the rest of life as possible.*
*-Edward O. Wilson, biologist, conservationist, author*

In November 2013, negotiators from nearly 200 nations worldwide met in Warsaw, Poland to discuss future actions to avert climate change. "Climate change is the greatest single threat to peace, prosperity and sustainable development," remarked UN Secretary General Ban-Ki Moon. The audience was well aware of the devastating effects of Typhoon Haiyan, which only days before had wreaked massive destruction and loss of life in the Philippines. Developing countries demanded that developed nations, having gained the benefit of unrestricted carbon pollution, bear the brunt of the cost of mitigating the effects of climate change. Developed nations, of course balked at this. Meanwhile, environmental and development groups walked out of the proceedings in frustration at the lack of meaningful progress.

Environmental issues are complicated and intimidating: climate change, ocean acidification, deforestation, food and water scarcity, sea level rise. These issues are inextricably woven into scientific, economic, social, and political structures. And they are likely to be the most important issues for the human race in the next century. It will not be easy to get the human race back on a sustainable path. There is no technological solution in sight that does not require economic sacrifice, social compromise, and political willpower.

But solutions will be found. Any real solution must reestablish environmental sustainability, of course. A real solution must also be socially and culturally sustainable, accommodating the preferences and needs of the people who must live with it. And of course, in our money-driven society, a real solution must be economically sustainable. This combination of "planet, people, and profit" is sometimes referred to as the "triple bottom line."

For many students, high school will be the last exposure to these subjects, the last real opportunity to develop a holistic understanding of sustainability necessary to become a well-informed voter, consumer, and citizen. Enabling our students to consider real-world problems from the perspective of a sustainable triple bottom line requires an understanding of the complexity of environmental systems; the multiple, often unpredicted or unseen, consequences of human interaction with the environment; and the incentives and motivators of human behavior. Integrating science, math, economics, and other social sciences into multidisciplinary projects is one possible path to reach this goal.

This is not an insurmountable task, but it is admittedly a tough change to make for the average classroom teacher. A more effective model would almost certainly involve a whole team of teachers working in close cooperation. SEEQS, though still a brand new school, may provide an instructive model to watch. Guided by the vision of Cushman-Patz, the Essential Question of Sustainability projects provide an opportunity for every student to explore a broad environmental issue through a lens of their own design, able to leverage the expertise of the entire faculty—science, math, social studies, English, technology, and art. For Kai, her worms are just the tip of the iceberg. Kai is just starting out in the inaugural year of SEEQS. By the time she graduates, six years from now, she will have experienced a dozen semester-long multidisciplinary projects, each one asking and answering its own essential question of sustainability.

Cushman-Patz likes to quote another influential educator, Karl Fisch: "We are currently preparing students for jobs that don't yet exist... using technologies that haven't been invented... in order to solve problems we don't even know are problems yet." She continues, "This next generation of students has to solve these problems, or else. In the next half a century if things don't change significantly, if we don't change our ways..." She trails off with a shake of her head.

Don't worry, Kai's got this.

**CITATION**

O'Hara, C. (2014). *Worms, bunny-huggers, and the triple bottom line: multidisciplinary projects for environmental education.* Kaleidoscope: Educator Voices and Perspectives, 1 (1), 15-23.

# WHEN RELATIONSHIP BUILDING FAILS

## BY JUSTINE MYERS

**Justine Myers** is a 2013 KSTF Teaching Fellow. In fall 2014, she began her second year as a California-based Earth Science teacher. Along with science, she has had a long-standing interest in teacher-student relationships. She wrote her master's thesis on the subject.

Those nagging thoughts kept me up all night; first just that one night, then the second, and now three nights in a row. Feelings of "I have done everything I could" wrestled in my mind, along with feelings of "what more could I have done?" This series of memories plaguing my mind originated from the unsatisfying experiences in the classroom with Jaz (a pseudonym), one of the students in my class. The events were unsatisfying not only because they were unexpected, but more so because this inability to resolve the relationship caused me to question one of my foundational teaching beliefs: building relationships with students can resolve all problems. I had always believed that as long as I put in the time, I would be able to find a way to help my students, independent of the situation. As someone with this philosophy, I was stumped by my experience with Jaz.

Three weeks into the first quarter a student I did not recognize, Jaz, sauntered into my classroom with a schedule change sheet. As usual, I introduced myself and gave him an open seat. Issues soon arose that consisted of Jaz repeatedly getting out of his seat to walk around the room and talk with his friends. Though these occurrences happened frequently, it seemed as if they were easily resolved with direct, respectful authority. I would address his behavior, and things would be fine for a bit. There was one week where he would not stop talking even when asked by me and his peers to be quiet, so I called home and the issue died down quickly. Though these issues were a hassle to deal with, I just saw them as minor issues. It seemed that my instincts for dealing with behavior by building a respectful relationship and showing concern with the family were paying off.

In the winter, Jaz's behavior and academic achievement improved dramatically. I soon found out that soccer season was coming up and he was the only freshman to make it onto the varsity team. Throughout the season, he would miss the usual week or so of class at a time because of soccer, but he would always come to talk to me about the work he needed to get done, which I appreciated incredibly. (I would only see his class every other day because of block schedule, so missing a week of school for a specific class was not uncommon.) Jaz seemed to be paying back into the relationship we had built by holding up his responsibilities during the soccer season.

Once soccer season ended, however, I noticed an escalation in his previous talkative behaviors along with a blatant disrespect for the relationship I thought we had built. When I asked him to do something, such as go back to his seat, he would either refuse or make faces and complain out loud to the class and to me. Thinking that our relationship needed more work, I pulled him aside after class to have a heart-to-heart with him. Those conversations seemed to go well, but their effect only seemed to last a few days at most. The first time, when I asked him why this was happening, he opened up and mentioned how pressure from his older brothers builds up and makes him act out in classes. After sharing that, I saw improvement for a day, but then he reverted back to how things were. I then tried other relationship-building tools such as praising his work when he did well, but the responses were neutral, which was not as positive as I expected. I brought in a support community by involving parents in phone calls and by connecting with the administration. The administration set up a plan with his soccer coach where he would be deducted a day's worth of practice any time he got in trouble. After this plan came into action, he refused to do any work in my class and would disrupt class activities. He even said in the middle of class that he wished he were back in the other class instead of this one. Soon after this, he was removed from all of his classes and placed in another program because the same behaviors were observed in his other classes as well.

The experience with Jaz has often made me question the success of my teaching. Many times people will ask me, "How was your first year of teaching?" And all the thoughts that flood my mind are mixed. I've seen such growth in some of my students, both as students and as people, and that makes me proud to the point of tears. Yet here was Jaz, a student that challenged all that I believe about the power of relationships to resolve any problem... What it came down to was I felt like it should not have ended this way, I felt unsatisfied, and I felt like I failed as a teacher.

While writing and reflecting upon Jaz, I wrestled with contrasting feelings of comfort and desperation. I remembered that a relationship is a two-way street; it cannot be built unless both parties are willing to invest. I was comforted by this at first because it reminded me that I was not solely responsible for building our relationship; Jaz had not been invested in our relationship, just in soccer. But it did not resolve the sinking feeling of why I could not connect with him and get him to care a little more. I had a wise teacher once tell me, "You can't get them all. The best you can do is to try to help them and try to build a relationship with them. And if that does not work, hopefully they are connecting with another teacher, because they do have seven other teachers." This brought me some level of comfort, because I realized that I had to believe this for teaching to be sustainable, yet I could not help but ask the questions: "Why does that have to be true? Why can't we reach them all?"

***Yet here was Jaz, a student that challenged all that I believe about the power of relationships to resolve any problem.***

I still do not have an answer, and I do not know if I will ever have a satisfying answer. What I do know is that my future years of teaching will be consumed by knowing that "I can't reach them all," yet still attempting to do just that. Though there is this tension, I walk into the new school year confident and full of optimism. I am fully aware of the vulnerability that is present when building relationships yet I have a new perspective on the reality of teaching. The unforeseen challenges that caused me to freeze with fear have now become a motivational force, knowing that if I give up there is no chance of building a successful relationship. If I persist then I have hope that every relationship can one day be successful. Ultimately, building relationships sometimes fails, but I will and must continue to try to build them.

**CITATION**

Myers, J. (2014). *When relationship building fails.* Kaleidoscope: Educator Voices and Perspectives, 1 (1), 24-25.

# BEING OPEN TO SURPRISE: CONFRONTING ASSUMPTIONS THROUGH A PUZZLING MOMENT

## BY KATE MARKIEWICZ

**Kate Markiewicz** is a KSTF Senior Fellow who has eight years of experience with chemistry, physics, and environmental science education. She achieved National Board Certification in 2013 and currently teaches in Massachusetts. Kate was a member of KSTF's Practitioner Inquiry for the Next Generation group from 2011–2014.

To be perfectly honest, during the fall of 2012, I wasn't expecting Jamie (a pseudonym) to be a very good science student, and I didn't know if Kylie (a pseudonym) could really learn chemistry despite the hours she spent working one-on-one with me. How was I going to teach them? These aren't the kinds of thoughts a good teacher is supposed to have, and certainly not verbalize them. They are dangerous. Yet it's the truth, and I wonder how education might transform if more teachers, administrators, parents, and even students felt safe enough to own up to, unpack, and reflect upon them. I would not have dared to share such misgivings just a few short years earlier until I became involved in practitioner inquiry and stepped back to reflect on what happened with another student, Elizabeth (a pseudonym).

Three years ago, I joined a nationwide group of math and science teachers (KSTF Fellows), KSTF staff, and education researchers Susan Lytle and Diane Wood to engage in practitioner inquiry—a form of teacher-driven professional development. We called our group PING (Practitioner Inquiry for the Next Generation). While all of the teachers in the group practiced inquiry as a vehicle for informing instruction, none of us anticipated how the inquiry process would transform the way we thought and acted as professionals, compelling us to be open to surprise about what was taking place in our classrooms and schools. Over the next few years, the way I viewed myself as an educator would change dramatically as we collected qualitative evidence (e.g., student interviews, journal reflections, student work samples, emails between colleagues) and used them to question and inform our research questions.

At our first PING meeting in the summer of 2011, we journaled about a "puzzling moment" from our teaching experience after reading an article by Cynthia Ballenger, which we then read aloud to the group. I shared a story about my experience teaching Elizabeth chemistry from the previous year. Elizabeth had informed me proudly at the start of the year that she wanted to be a scientist. I can still picture her now, sitting in class, her hand raised high above her head. Elizabeth's hand was always raised high above her head. "Ms. Markiewicz, can you explain that again?"; "Ms. Markiewicz, did you know…"; "Ms. Markiewicz, have you heard the pun about…"; "Ms. Markiewicz, I don't understand…"; "Ms. Markiewicz, wait till you hear what Tim said about…"; "Ms. Markiewicz, I wonder why…". Elizabeth was a dominant voice in class, seemingly incessantly asking about a topic her classmates had just discussed and summarized. Every whole class conversation—opener question, brainstorming session, summarizing discussion, etc.—I knew I would see her hand raised high in the air. Elizabeth had something to ask or say, frequently whittling away at 5 or so of the pithy 45 minutes of daily instructional time. She was a social butterfly, occasionally fixing her makeup in class, wearing clothing that left little to the imagination, and flirting with her male classmates. Her homework completion was inconsistent and performance on assessments was below average. For all her questioning, she seemed to be learning very little.

I try to run a very open classroom founded on students asking questions and sharing ideas. However, after several weeks, I began to feel irritated by Elizabeth, and I gritted my teeth each time I saw her hand start to go up. I would attempt to say, "Yes, Elizabeth?" in an inviting manner, but meanwhile, I would be thinking "What now?" As time went on, Elizabeth continued to struggle to pass the class, and I observed she became quieter and gradually raised her hand less. If I am honest about it, I felt relieved. Class discussions felt more productive because we would reach the end of my lesson plans before the bell rang, yet Elizabeth never did achieve very highly in chemistry that year.

I am not proud of what happened with Elizabeth in my chemistry classroom. I really feel that I failed her. I have a lot of clear evidence from student interviews, written reflections, formal assessments, and individual conversations that I help many students connect with science and become inspired to learn more than they thought they could. The story of Elizabeth doesn't seem to fit with the narrative of an educator who is a KSTF Teaching Fellow, Theodore William Richards Award for Excellence in Teaching Secondary Chemistry recipient, and National Board Certified Teacher in Adolescent and Young Adult Science. Yet I suspect most teachers have had an "Elizabeth" in their classrooms who they know isn't learning and who they don't do more for because they don't have the mental energy.

When I stepped back to examine the situation with my PING colleagues, I learned the power of being vulnerable and open to surprise. After sharing my narrative, we followed a collaborative feedback protocol that engaged us in rounds of probing questions about our stories. These probing questions made me reflect on my assumptions about the incident. I realized I didn't know why Elizabeth was so full of questions, I had just assumed she was attention-seeking. Was she trying to show me just how interested she was? Were her repetitive questions because she struggled to maintain attention? Or was she just trying to make sure she understood the content? Was she hoping that if she participated a lot I would notice her more? Were my assessments really gauging her learning? While I will never know, I now keep these questions in mind whenever I sense I might be encountering another "Elizabeth" in my class. Her story stays with me—continually reminding me to try to avoid presuming a student's motivations and to examine my own biases.

***Her story stays with me—continually reminding me to try to avoid presuming a student's motivations and to examine my own biases.***

I worry that I negatively impacted Elizabeth's science experience, but almost three years later I am still learning from reflecting on our teacher-student dynamic. As I continued with PING and practitioner inquiry, I began to wonder where else in my practice I was influencing the way my students relate to science. Where else in my teaching practice was I making potentially false assumptions? Through this initial (and seemingly tiny) piece of data—my narrative about Elizabeth—my practitioner inquiry research question was born: *How am I affecting the science identities of my students through the relationships I develop with them?*

Over the course of my time with PING, I went on to interview students such as Kylie and Jamie about their science experiences, wrote journals, and ultimately explored how my own experience in learning science influences my motivations for and approach to teaching science. All of this  invariably led to more puzzling moments. Why had I assumed Jamie would not be a science-oriented student? Is it ever a teacher's place to tell a struggling student like Kylie that she might want to consider other avenues of study beyond the sciences? Practitioner inquiry has not given me a generalizable answer for these questions or the many others that have come up along my journey, but it has helped me to acknowledge that they exist and seek to better understand them in the context of a given student. In the words of Diane Wood, "Practitioner inquiry is not generalizable in the way we think of it. It is generalizable in the sense that it is evocative, and it resonates with others, and allows them to see a potential change in their own context. That is a type of generalizability that is different than others."

So how is my teaching changing or my students benefitting from my exploration of puzzling moments and my inquiry question? The product of my three years of work is not an improved test score, because I can't measure the effects of reflection in a clean, quantitative way. However, I am sure my students have benefitted from my inquiry. There are tangible outcomes. I have begun to get to know my students more deeply through interviewing a handful of them each year, causing me to ask more questions of myself and my teaching. I am better able to question my assumptions about why a student acts a certain way. I formed a Critical Friends Group at my school to help others in my local context get a feel for what inquiry on a small scale can do. I wrote a science education autobiography, which showed me some of the parallels between my students' experiences and my own as well as my motivation to support students in science. I also gained an appreciation for how working on others' inquiries and asking dangerous questions can shed light on my own practice.

In our current education climate, which often views educators as the *problem* rather than the *solution*, it feels especially risky for teachers (and others involved in education) to admit we don't know the answer or to examine our assumptions openly. As I stated earlier, this is not something I could have done three years ago. It required significant time, extensive practice in using protocols to unpack my assumptions, and a high level of trust and shared sense of responsibility between members of the practitioner inquiry group. By being willing to ask questions about our practice teachers can reach deeper questions, and by situating ourselves as protagonists in the story (only we can change—we cannot force change upon others), I am certain we as educators can make incremental and powerful progress towards improving educational outcomes for students like Jamie, Kylie, or Elizabeth.

## FOR RESOURCES ON PRACTITIONER INQUIRY, SEE:


Ballenger, C. (2009). Puzzling moments, teachable moments: Practicing teacher research in urban classrooms. New York: Teachers College Press.

Cochran-Smith, M. & Lytle, S. L. (2009). Inquiry as stance: Practitioner research for the next generation. New York: Teachers College Press.

Lytle, S., Christman, J., Cohen J., Countryman, J.,Fecho, N., Portnoy, D., & Sion, F. (1994). Learning in the afternoon: When teacher inquiry meets school reform. In M. Fine (Ed.), Chartering urban school reform (157-179). New York: Teachers College Press.

Stokes, L. (2001). Lessons from an inquiring school: Forms of inquiry and conditions for teacher learning. In A. Liberman & L. Miller (Eds.), Teachers caught in the action: Professional development that matters (141-158). New York: Teachers College Press.

Wood, D. R. (2011). And then the basals arrived: School leadership, learning communities and professionalism. *International Journal of Leadership in Education*, 14(4), 475-97.

Wood, D. R. (2010). Learning communities: Catalyst for change or a new infrastructure for status quo? In B. L. Whitford & D. R. Wood (Eds.), Teachers learning in community: Realities and possibilities (41-71). Albany: SUNY Press.


## CITATION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