What a Middle School learned about Environmental Sustainability, Sustainable Food Systems, Arduino...

Conference Paper · September 2016

CITATIONS 0
READS 14

5 authors, including:

Mishael Sedas
Indiana University Bloomington
3 PUBLICATIONS 0 CITATIONS

Christian Mckay
Indiana University Bloomington
6 PUBLICATIONS 1 CITATION

Some of the authors of this publication are also working on these related projects:

ReCrafting Mathematics Education: Designing Tangible Manipulatives Rooted in Traditional Female Crafts View project
What a Middle School learned about Environmental Sustainability, Sustainable Food Systems, Arduino, and Aquaponic Farming

Tarrey Banks  
The Project School  
Bloomington, Indiana  
United States

Scott Wallace  
The Project School  
Bloomington, Indiana  
United States

Krista Glazewski  
PhD, Indiana University  
Bloomington, Indiana  
United States

Mishael Sedas  
Indiana University  
Bloomington, Indiana  
United States

Christian McKay  
Indiana University  
Bloomington, Indiana  
United States

ABSTRACT

Educators from The Project School and collaborators from Indiana University (IU) forged a unique partnership that supported middle school students over the course of a yearlong, multidisciplinary design project. The project engaged students in a broad question: Can DIY (Do-It-Yourself) aquaponic systems solve sustainability problems associated with the industrial food system at home and abroad? In this context, students designed and built tabletop automated aquaponic systems while simultaneously engaging in questions of food sourcing and labor. The majority of learning can happen inside the long term, hands-on, design-based project rather than using it as a supplement or assessment.

Keywords
Aquaponics; Arduino microcontroller; community partnerships; design; environmental sustainability; makerspace; middle-school; project-based curriculum; 3D printing.

1. DESCRIPTION
1.1 Setting description
The Project School (TPS) in Bloomington, Indiana, is a nonprofit-chartered public school with independent board governance. TPS’ founders were educators with essential core beliefs such as, empowering students and their families, valuing all members of the school community, creating individualized educational experiences, teaching for heart, mind and voice, and creating educational equity. This philosophical stance is infused in our school. Social justice and environmental sustainability are paired with educational excellence in our classrooms, curriculum, family programming, and special events.

Who are TPS’ students?
➢ 277 students, kindergarten through grade 8, from Bloomington, Monroe County, & surrounding communities in Indiana
➢ 95%+ annual enrollment retention rate
➢ 36% of students are eligible for free or reduced lunch
➢ 22% of students have Individual Education Plans (IEPs) to support special learning needs

Curricular framework: Problem, Project, and Place-based learning

TPS utilizes a uniquely designed curricular framework: problem, project, and place-based learning (P3). P3 ties together the hard sciences, social sciences, history, and civics with our interdisciplinary reading, writing and mathematics curriculum, which directly connects to issues in the local and global communities. Students, teachers, families, and community members work together to arrive at school-wide topics and essential questions that guide individual, group, and community projects. Students understand that they can make a difference in their communities, and the community sees the school as a force for social justice.

Maker-centered/hands-on learning environment

Our classrooms are fully inclusive for students of all abilities and needs and are designed as multi-age, co-teaching spaces to allow for peer leadership and mentorship. The educational experience described in this paper happened in our middle school classrooms. TPS’ middle school classrooms have an open configuration with an integrated makerspace. This makerspace has a tool station, textile screen printing machine, 3D printer, and laser cutter (see Figure 1 above). In recent years, we have collaborated with faculty and students from Indiana...
University School of Education. These collaborators have provided, not just tools and materials to create a makerspace for our school, but innovative practices and support with implementation and professional development on emergent technologies.

1.2 Description of the educational experience
During the 2015-2016 school year, 60 middle school students (grades 7 and 8) with our team of teachers and collaborators from IU, engaged in a yearlong project and problem-based exploration of sustainable food systems and aquaponic farming. This project was multidisciplinary in nature and connected to a larger yearlong study of food systems and solutions.

We introduced students to the concept of aquaponic farming comparing it to more traditional methods of farming. Students analyzed the effect food choices have on the environment as well as how to mitigate those effects. Ten teams, of four to six students, each designed and made an aquaponic farming system utilizing the steps from Stanford’s d.school design model: empathize, define, ideate, prototype, and test. Each student on the team had a designated job, either team leader; flora/fauna, water chemistry, or automation/maintenance specialist; or historian. We followed the technical paper “Small-scale aquaponic food production” (from the Food and Agriculture Organization of the United Nations [1]) to learn basic principles and to guide our project, from construction, to maintenance, to installation. At the beginning of the school year, we posed the following design problem/challenge to the students: Design a self-sustaining, closed-loop aquaponic farming system that takes up the footprint of a classroom tabletop.

Design and construction of the Aquaponic System
Students began with an in-depth study of aquaponics followed by multiple design iterations that included: sketches, conceptual models, technical drawings, and fabrication of working systems in our makerspace (Figure 2). Students had only loose guidelines for how they could design their systems and what materials they could use. Each team designed a different system that met these criteria in very diverse ways. Throughout the year, students maintained, modified, and problem-solved their aquaponic systems to improve their yields, and keep their systems fully functional.

Automation system powered by Arduino UNO
A critical component of this project was integrating technology to the aquaponic system as a way to introduce students to electronics and programming. The task was to create an automation system using Arduino microcontrollers for monitoring water temperature and water level, and designing and fabricating an automated feeding system for the fish. Partners from IU helped co-design and fabricate these automation systems with our students and teach them how to test and install them in each aquaponic system [2] [3]. One of our IU partners and one of the teachers, team-taught a series of weekly sessions guiding students in the wiring of the automation system and explaining the affordances of the Arduino to create interactive systems (see Figure 3).
Our automation systems consisted of one Arduino UNO microcontroller board, one ultrasonic distance sensor (to continually monitor the water level of the system), a waterproof temperature sensor (to monitor water temperature specific to the species of fish), and a continuous servo (to drive a student-designed fish feeder). The system also had an alarm subsystem and a backup clock with current date and time. The alarm subsystem consisted of one small buzzer and four small lights (LEDs). If the water temperature passed predetermined values, the red (too warm) and blue (too cold) lights would light up and the buzzer would sound alerting the students. Otherwise, temperature values in the acceptable range were indicated by the green light. Similarly, if the water level was beyond predetermined height values, the buzzer would sound and a yellow light would turn on. Another important subsystem was the backup clock or real-time clock (RTC) module, which would maintain the current time and date regardless of the microcontroller losing power. The RTC was vital to allow the fish feeder to pour the food into the fish tank at the exact time, every day.

Students were not required to create the code for each sensor and subsystem from scratch, but every automation leader was exposed to the code and to the basic concepts of programming in the Arduino Software (IDE). Each automation leader was able to locate and change various parameters in the code, such as sensors’ data inputs/outputs, and temperature ranges. Finally, each team’s design leader used SketchUp™ or Tinkercad™ to design the fish feeder and a case or box to house the automation system.

Questions on sustainability problems, food sourcing, and labor

Students engaged in a broad question for this whole project: Can DIY aquaponic systems solve sustainability problems associated with the industrial food system at home and abroad? As students designed and built their automated aquaponic systems, they also completed multiple learning activities on sustainability, food sourcing, and labor. Students engaged a close reading of Michael Pollan's book Omnivore’s Dilemma. This reading served as a springboard into concepts around sustainability related to food and food systems. In addition, this reading was helpful to develop strategies for close reading of other challenging non-fiction texts and multimedia that could either share Pollan’s position or oppose it. Students also engaged in a micro-research project on the history and root causes of one specific problem connected to food systems, couched that problem within sustainability, and posed their own thinking and potential solutions to the problem. Students also engaged concepts of labor, labor organizing, and immigration as it relates to our industrial food system. Through exploring Cesar Chavez and other labor movements throughout US history, students looked critically at who is producing the food in this system and how those people are treated.

Learning goals and State Academic Standards

The overarching learning goal for students was to design a close-looped, self-sustaining aquaponic system, and critically analyze the practice of aquaponics as a solution to food supply issues. However, there were also multiple learning goals and state academic standards addressed, practiced, and mastered during this yearlong project. Below is a sampling of those goals from each of the major subject areas and/or disciplines. Students would:

In English Language Arts (ELA)
- Acquire multiple strategies for critically analyzing non-fiction texts
- Effectively use multiple forms of text in their writing to construct a compelling argument or position

In Humanities
- Understand and be able to articulate pros and cons to each of the major food supply chains in the United States (industrial, industrial-organic, local-sustainable, hunter-gatherer)
- Identify multiple food systems related issues, trace those issues to their source, offer ideas around cause and effect, and identify potential solutions to those issues
- Understand the connection between labor rights, wage disparity, immigration and migrant-workers to the industrial food supply chain in the United States

In Science
- Compare and contrast the nitrogen cycle in both traditional and aquaponic farming methods
- Understand and be able to identify the complex systems within living things (including fish dissection) and the interaction between them (digestive, circulatory, etc.)
- Observe and explain the process of photosynthesis central to the energy cycle of animal ecosystems
- Begin to develop an understanding of basic chemistry due to the central principle of converting ammonia to nitrite and nitrate for plant uptake in aquaponics

In Collaboration:
- Identify the skills and dispositions of an effective team member and reflect on themselves as team members
- Develop problem-solving strategies for teamwork
2. CONCLUSION

2.1 Results

The frequent reflections and students’ involvement in decisions about curriculum appeared to make huge impacts on our students, some even life changing. Many students told us that they had begun to change their own behaviors as a result of what they were learning. In parent-teacher conferences, parents reflected that their children had never talked about school so much and that they were sharing what they learned with everyone they shared a meal with. Students moved from seeing themselves as “consumers” to “makers or producers.” Several students built aquaponic systems at home, and every final aquaponic system (Figure 4) was taken home at the conclusion of the school year to a family who wanted to continue the work. As educators, we also learned about these food system issues alongside the students and began making changes in our own lives (e.g. joining a local Community Supported Agriculture for our own family’s meat).

Throughout the project, one challenge that kept coming up was trying to assess when to step in with teams and when to let them manage their own problems and struggles on their own. While this was a perceived challenge for our teacher team, in our summative assessments, students reflected that one of the strengths of this project, and project based learning in general, is having loosely structured guidelines and letting students figure out their own problems as they come up.

Students were very clear and articulate in saying they did not want adults hovering over them and solving all their problems. One element that could be improved is our connection with the local farming community. While we attempted to work with local farms and aquaponic organizations, we were not successful in getting our students out into the community enough. We believe this is a critical element for our P3 model as we move forward. However, close to the end of our school year, a local nonprofit organization connected us with a middle school classroom from College de Savoirs in the Democratic Republic of Congo (DRC). Both schools joined in a Skype call where each of our schools’ teams presented short videos [4], discussed their farming project, and talked about its benefits. The exchange was one of the most meaningful and impactful moments of the year for many students in the classroom.

2.2 Broader Value

This extended project represents a shift in conventional thinking regarding the integration of classroom design projects. Teachers committed to project based learning often implement projects in discrete chunks and use projects as a form of summative assessment after teaching content in traditional ways. In our classroom, the project was the main vehicle of curriculum delivery, integrating literature, composition, science, social sciences, and math. While there will always be some explicit standards that need to be taught and may not fit nicely into a project, we suggest that the vast majority of learning can happen inside the long term, hands-on, design-based project rather than using it as a supplement or assessment. We have also demonstrated how teachers can turn their classrooms into maker-centered spaces without a top-down mandate from the administration or district. Projects like this one demonstrate that students can do incredibly complex and challenging work that has real implications for their lives and the communities they live in. Moreover, we suggest that the multidisciplinary nature of the work may foster critical learner investment in the project, potentially leading to persistence during tiresome troubleshooting, significant engagement, and generally positive learner satisfaction.

2.3 Relevance to Theme “Diversity in Making: People, Projects, & Powerful Ideas”

The diversity of people, activities, and ideas in this ambitious project produced the educational richness found in the outcomes. As mentioned previously, some students started building aquaponic systems at home, others started going to camps to learn more about Arduino microcontrollers, a teacher joined a local Community Supported Agriculture, and students felt empowered by sharing their findings on aquaponic farming to solve problems in Africa. In Africa? Yes. It was interesting to witness how our students felt they were playing an important role in advocating for the students of College de Savoirs in their quest to design and implement a learning garden in a place where traditional farming methods present challenges [4]. Seeing beyond the classroom into the lives of those connected to this project allowed a greater sense of agency and empathy to develop in the classroom.

Figure 4. Examples of Aquaponic Systems
3. BIOS

Krista Glazewski, Ph.D., is an associate professor of Instructional Systems Technology at Indiana University and serves as co-editor of The Interdisciplinary Journal of Problem-Based Learning (PBL). For almost fifteen years, she has been engaging in the scholarship of PBL, exploring questions of curricular design, student engagement, and teacher support / professional development.

Tarrence Banks (Member of Panel). Mr. Tarrey is a graduate of Butler University with a B.S. in elementary education. He received his MA in school administration from Indiana University and is currently a Ph.D. student at Prescott College focusing on sustainability education. He began working with The Project School Founding Group in the fall of 2006, and is on the 7-8 team focusing on humanities and P3.

Scott Wallace. Mr. Scott has been teaching middle school for six of his eight years of experience. He loves teaching. Originally trained as a chemist, he fell in love with teaching when he was in graduate school and decided to pursue a teaching career. His B.S. in Chemistry is from Lebanon Valley College (Annville, PA) and his MAT in Chemistry is from Indiana University, in Bloomington. He loves all things “techy” and dabbles in homesteading on his property in rural Springville, Indiana.

Mishael Sedas. Mishael is a Ph.D. student in Learning Sciences in Indiana University. He is currently working with advisor Dr. Kylie Peppler as a member of the Creativity Labs @ Indiana University (http://creativitylabs.com). He has a B.S. degree in Mechanical Engineering and a Master’s degree in Public Administration with an emphasis in Nonprofit and International Development Management, both from Brigham Young University (BYU). While working for an international nonprofit organization helping people in developing nations attain access to education, he developed an interest in the use and creation of innovative technology to foster learning, especially in STEM subjects and for low-income populations.

Christian McKay. Christian is the makerspace coordinator for IU’s School of Informatics and Computing Intelligent Systems Engineering program. With an MFA from California College of the Arts, and as a fifth year doctoral student in IU’s School of Education, Christian’s educational research interests lay with teachers engagement at the intersections of design, craft, and technology in the classroom. He is a longtime collaborator with The Project School helping bring digital fabrication technology into the classroom for K-8 children.

4. REFERENCES


[4] Example of videos created by students about Aquaponic Farming and shared via Skype with a classroom from College de Savoirs, a middle school in the Democratic Republic of Congo https://iu.box.com/s/1ngwk9udzdpjubbptzx6of9264r0n42