Mayor and Superintendent Collaborate on Unique Opportunity to Develop Partnerships and Create Authentic Learning Opportunities for High School Students Through STEM Education

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INTRODUCTION

Research shows that authentic and problem based education are extremely beneficial for the complete development of learners. Dennis (2010) discussed the obstacles and effectiveness of raising student achievement using authentic instruction in education while Flowers (2016) researched the need to connect high school students to science professionals using authentic field research experiences. Both researchers discussed the benefits and need to develop authentic research projects in education systems. Millenbah (2003) and Edens (2000) focused on the improvement in developing better problem solving and decision making skills from real-world experiences. Both, improving problem solving, and decision making skills lead to improving competence which leads to increased student confidence. Millenbah developed experiential learning practices in wildlife courses to improve retention, problem solving and decision-making. She found that adopting new pedagogical techniques can be both difficult and intimidating, yet very satisfying and absolutely worth the effort. Edens studied the use of problem-based learning to develop 21st century problem solvers. PBL is a change from traditional education and tends to increase both teacher and student work loads. Findings showed students' perception was that they developed better problem-solving skills, improved positive attitudes and increased confidence.

Dr. Adam Boddison, Chief Executive at the National Association for Special Educational Needs (n.a.s.e.n.) believes that teachers are pivotal in changing the culture of education. He contends that while the system needs to provide a safe environment for learning, students must be exposed to real world situations. According to the Kauffman Foundation, a survey of more than 2000 participants, 26% of high school students feel the job they will hold in 20 years has not been invented yet. So how do high schools prepare students for an unknown future? 75% of the parents in the study say “a high school degree should primarily focus on providing students with the skills needed to succeed in the real world” (which could include higher education). The parent voice of reason sees the need to prepare students for more than just the “college experience.” According to the survey, employers are putting an emphasis and skills that only humans can provide, which means creativity, perseverance and group problem solving will be key. The role of education is to give students real world learning opportunities and to foster skills that are employable.

All of these studies show the importance of authentic hands-on learning opportunities and the benefits to student learning and the important role teachers play. The research that is being conducted at CERF models these characteristics.

BACKGROUND

Village of Minoa (NY) Mayor Richard Donovan had a vision to incorporate the Waste Water Treatment Plant facility in creating research opportunities for local high school students. In collaborating with East Syracuse Minoa Central School (ESM) Superintendent, Dr. Donna DeSiato, the two of them paved the foundation for authentic hands-on research and the Cleanwater Educational Research Facility (CERF) was born. This partnership changed teacher roles and classroom culture allowing students the opportunity for real-time research and a deep understanding of clean water and alternative energy topics. My wife, Pamela, and I, co-teachers of the research class, were tasked with furthering the partnership and leading students and their research visions. Our traditional teacher-role required a great deal of flexibility, vulnerability, and humility, as it was nearly impossible to be an expert in all of the student research specialties, nor to be one-step-ahead of the emerging projects' physical material needs.

DEVELOPING RESEARCH OPPORTUNITIES

The research process started off small (having only 5 students). Our first question was to determine which material produced the most heat through the process of decomposition. At CERF, students took temperatures using a 36" thermometer, of individual leaf, mulch and wood chip piles. The piles were approximately 6' by 6' wide and 6' high. Data collection took place weekly from October to March. It was determined that the leaf pile produced the highest and most sustainable heat. The research process was more in depth then just taking pile temperatures. Students researched peer reviewed articles on sustainable heating practices, year round gardening, and how the decomposition process produces heat. Students' findings were presented to students and faculty at the State University of New York College of Environmental Science and Forestry's (SUNY ESF) Environmental Summit.

The following year's research focused on heat transfer from the leaf pile to an insulated shed. Students were capturing heat from a 40' by 40' by 12' high leaf pile to heat a 12'x12' insulated shed in hopes of growing vegetables year round. Students developed a research plan and then began construction of their research site. Students spent the first few weeks, installing radiant floor tubing, insulating, and bringing soil into the shed, which we referred to as the "Brownhouse." Weather data, air temperature, and soil temperature were collected in the brownhouse weekly. While sustainability is our primary focus with the research projects, students realized the inevitability of using

lights to make sure our plants grow. Our goal was someday to have a real greenhouse to conduct research. Students attempted to grow peas, lettuce, tomatoes, spinach and kale. Lettuce was the most successful. Students learned many things from this research: soil nutrient needs, humidity levels and air movement (or lack thereof) affect plant growth, and proper lighting for proper fruit growth. While not many vegetables grew or fruited, a tremendous amount of knowledge was gained through this hand on learning process. In real-world research, things go wrong, failure is part of growth. Part of the research process is connecting with professionals in either higher education or individuals in the business world.

Research in the brownhouse continued for a few years, with each year students researching different ideas and parameters. All of which were student driven ideas. Finally, my wife, Pamela, successfully applied for a grant through NOAA's Climate Steward's program (National Oceanic and Atmospheric Administration) and our present greenhouse was funded.

A representative sample of research projects that are presently conducted includes: how constructed wetlands purify water, how a biodigester uses waste water to make biogas, the process in making biofuel from microalgae, how aquaponics and hydroponics systems work, and the ability to heat a greenhouse through the decomposition of a leaf pile. When teachers are allowed to facilitate learning, not dictate facts on an exam, teacher and student interactions are altered in a way that allows for increased collaboration, productivity, and trust; One step closer to the educational system preparing students for the real world after high school.

The aquaponics system (Figure 1) students' design includes a biofilter, goldfish tank, lower pond and grow beds. Students collected data on plant growth, fish growth, ammonia levels, dissolved oxygen levels and temperature. In figure 2, after design failures from a different group the previous year, this student designed a system to heat the photobioreactors and grow algae with the hopes of producing a biofuel. Real-world research projects require constant problem solving. Problem solving the heating of a large greenhouse, students came up with a design to build a greenhouse within the greenhouse to grow vegetables year round (Figure 3). This space is heated from water in tubes that are circulated through a large leaf pile outside of the greenhouse then into the greenhouse and then circulated beneath the soil in the inner greenhouse.

While these hands-on, real-world research experiences are unique to our situation at ESM, other schools can develop these opportunities for their students. Developing the partnership and connecting with professionals - having the right players in the right positions - is the key. Developing authentic research opportunities requires a tremendous amount of planning and support from administration. What we have seen in the development of our students, not just knowledge, but collaboration, problem solving, time management, research skills, and I feel the most important skill is dealing with failure or setbacks.

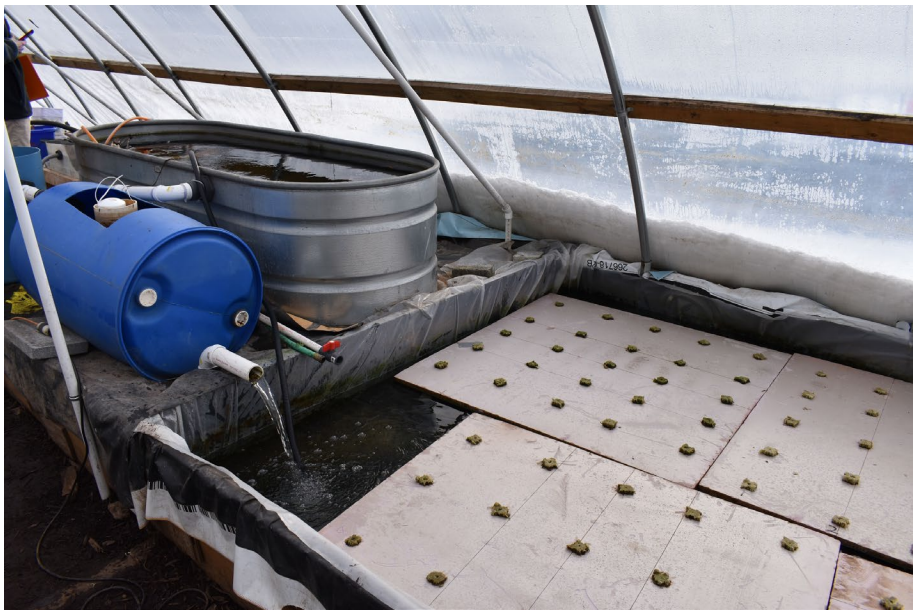
1. 

Figure Aquaponics system in the greenhouse.

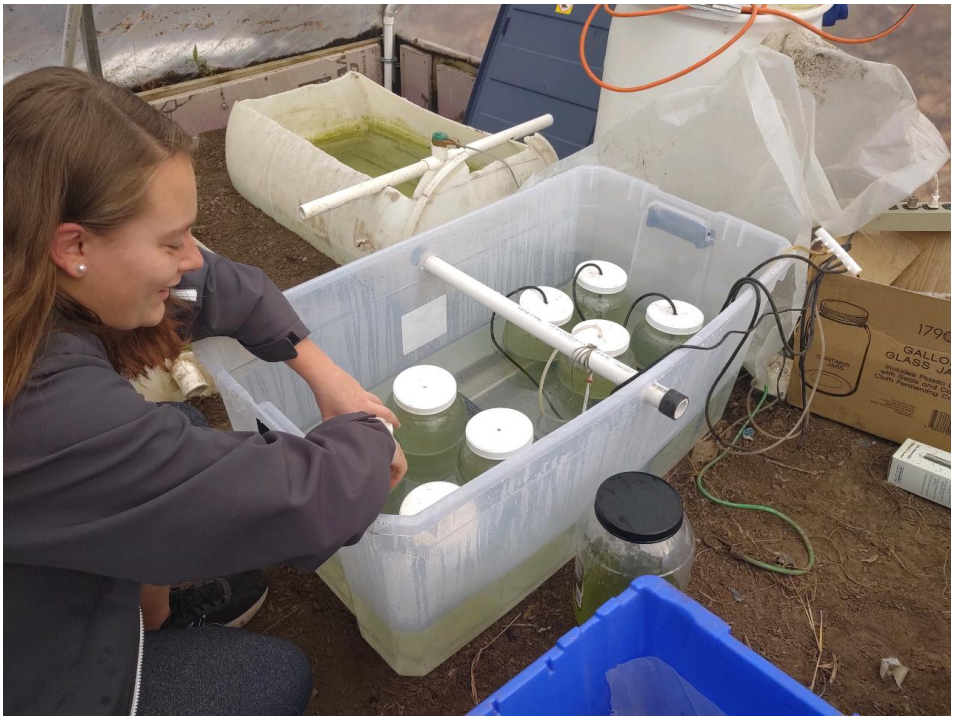


Figure 2. Student growing algae in photobioreactors.

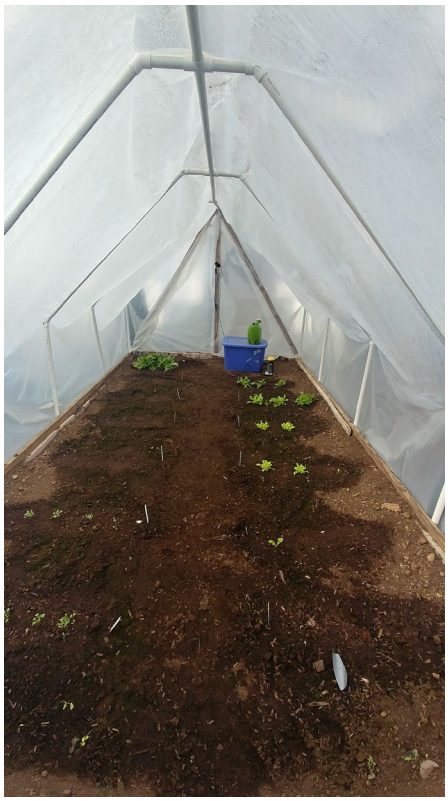


Figure 3. The greenhouse within the greenhouse.

DEVELOPING PARTNERSHIPS

Critical to the success of CERF were the individuals supporting the vision from all partners; however, there were barriers that are worthy of note. Logistics of transportation, developing feasible research projects, connecting students with appropriate mentors when needed, garnering collegial support from competing electives, and adapting a teaching style to best fit the needs of the learners in this new educational environment. It is also worthy of note that I speak to the integral role played by Dr. DeSiato. Without her encouragement to think outside of the box, constant support, both budgetary and professional, or her constant messaging of her belief in multiple measures of student achievement and performance, my wife and I would not have taken the necessary risks to ultimately succeed. Having the support of our Principal Greg Avellino has been another reason for the success of the CERF program. Knowing that administration has “your back” and supports you taking risks is very reassuring and has allowed us to focus on developing our skills and supporting students through these unique learning opportunities.

Having this special research opportunity for students also brings some special needs. Obviously having an unlimited budget would be ideal, unfortunately we were on a “shoestring” budget. Some materials are purchased through our traditional science budget but we have gotten good at repurposing items that have been discarded at the DPW by local villagers such as doors, water containers, hoses, pvc piping and wood. Our Superintendent has also provided additional unforeseen resources. Because we are partnered with our local village, we have access to some of their resources such as tools, lab equipment and most importantly, brain power. Input from the Waste Water Treatment / CERF staff has been invaluable. They work with students advising on project designs, problem solving and lending their expertise when needed. There are times when heavy machinery is needed and the workers are always willing to help. Developing grant writing skills has been an important asset for this “shoestring” budget. We have purchased a greenhouse, water tanks and supplies through grants from NOAA and the ESM Education Foundation.

RESULTS

The results from 18 ESM graduates (2011 - 2018) and 8 current ESM students that took the class the last two years, responded to a short survey (26 total students). Of the 18 alumni that responded, 11 of them went into a science related field.

What skills or learning opportunities did you develop through your CERF research experience?

Collaboration or Teamwork:	81%
Time Management:	69%
Problem solving:	54%
Presentation Skills:	46%
Data Collecting / Interpretation Skills:	42%
Dealing with Failure / Setbacks:	39%
Research Skills:	27%
Goal Setting	8%

Feedback from our students is more evidence that we are heading in the right direction with this research program.

"The class allowed me to do hands on projects, think outside the box, and learn completely new things. Global Environment made me realize that I was extremely interested in the environmental sciences, and gave me clarity on what to study in college."

"Overall this experience was a great introduction to college level learning that allowed me to combine my background knowledge in science with problem solving skills to answer a research question that is applicable to the real world."

"This class is unlike any other high school class. The teachers are phenomenal at being mentors, but allowing students to use their own ideas to create new projects, studies, etc. I loved every second of it. I was the first class to start working with CERF, and it's unbelievable to see how much the program has grown, and what current research the students are doing today. The projects are complex, exciting, and apply to today's world issues."

"This was an awesome class and it was a great feeling at the end of the year seeing all of our work/data come together along with the physical results; it's something that I still talk about and I know my partner still talks about. Being able to work at CERF was such a unique experience and helped make me realize a job in the field as opposed to a desk job was something that I really wanted to pursue."

"My experiences at CERF truly contributed to my life. I gained skills that helped me adapt in my life outside of CERF. The class is like a family to me; everybody

connects with each other. I wouldn't trade my experiences with the class or CERF for anything. I'm so appreciative that I was given the opportunity to conduct my own experiments off campus, and especially, being able to continue my research next year."

Student responses and reflections on dealing with failure or setbacks helped them through their journey.

"CERF taught me how to focus on the positives; how to fix the issue and adapt to move forward. Even though failure was a part of my project last year, I am using it to make further changes and push myself towards a successful harvest this year."

"At CERF, every project in some way failed. Though that experience I learned that failure doesn't mean that you didn't succeed, rather that your project took a different course than you had expected and you grew and adapted with it."

"In other classes, failure has always been something that is highly avoided and looked down upon; however, by facing failure during my research at CERF, it not only taught me how to overcome failure, but to accept it and expect it."

"Through my CERF research experience, I was able to learn that failure is one of the best ways to grow, and although it can be frustrating, failure provides an opportunity to rethink your approach and look at the project from a different perspective."

The survey responses are powerful and demonstrate what students are getting out of this unique real world learning opportunity.

As co-teachers of this research class, my wife and I have witnessed many successes in taking risks and developing these types of opportunities for students. My wife, Pamela's, biggest take away from the student experiences at CERF is that "Competence builds confidence" is one of the reasons our students are successful at the next level. Students develop important skills through the rigorous engineering process which prepares them for the transition to college. Also, with the opportunity for a variety of research projects, students are being exposed to different career possibilities.

I am a strong believer in preparing students for their next adventure in life, developing the whole student.These research projects empower students to take charge of their own learning and allow students a safe environment to fail. These are real world research projects, things go wrong, things break, fail etc. Students learn that failure is a part of research, it is a set back that they must overcome and solve. Learning from failure and setbacks is a crucial component in preparing students for life.

CONCLUSION

Creating CERF and evolving our teaching skills and projects, in order to create the best science research learning experience for our students has been a labor of love.

We gladly spend time thinking about all-things-CERF in the small hours, summers and school vacations, and long after the students have moved on to their next chapters, because as teachers, we have been called to prepare the next generation of scientists.

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