2019

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Recommended Citation

Day, Ryan (2019) "Weather Courtyard: Reflections on Interactive STEM Learning Spaces," *Purdue Journal of Service-Learning and International Engagement*: Vol. 6 : Iss. 1 , Article 7.

DOI: 10.5703/1288284316981

Available at: <https://docs.lib.purdue.edu/pjsl/vol6/iss1/7>

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WEATHER COURTYARD:

Reflection on Interactive STEM Learning Spaces

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STUDENT AUTHOR BIO SKETCH

Ryan Day is a sophomore and civil engineering student at Purdue University, and served as design team lead for the Delphi Community Elementary School (DCES) EPICS project. He intends to pursue a career in environmentally focused civil engineering. In fall 2018, Day began serving on this project's inaugural semester, with the project aimed at creating a better-utilized courtyard space at a local elementary school. This article reflects on his experience designing and delivering a weather station project.

ABSTRACT

Ryan Day is a sophomore and civil engineering student at Purdue University, and served as design team lead for the Delphi Community Elementary School (DCES) EPICS project. He intends to pursue a career in environmentally focused civil engineering. In fall 2018, Day began serving on this project's inaugural semester, with the project aimed at creating a better-utilized courtyard space at a local elementary school. In this article, he discusses his experiences in service-oriented engineering developing an interactive weather station for DCES students. Day details this process and the lessons learned over the course of the project development, as well as the project's influence on his aspirations for a career in civil and environmental engineering. To provide substantive takeaways from the project, he concludes by reviewing the benefits of interactive STEM learning spaces in the instructional environment and links them to the impacts of the weather station project on the community.

INTRODUCTION

After applying to Purdue in fall 2017, I was drawn to the Engineering Projects in Community Service, or EPICS,

learning community. I had long been involved in different forms of science and STEM outreach, and in high school served as a science camp coordinator for Parents as Teachers of Porter County and as a Science Olympiad volunteer. I saw EPICS as an extension of this and a way to further my passion for community outreach.

EPICS was founded at Purdue with the goal of enhancing civil engagement through engineering. Membership in the EPICS learning community requires taking a modified EPICS version of the First Year Engineering general engineering class in the fall semester, as well as two semesters of a one-credit-hour EPICS lab, where the actual community service project participation takes place. Each student is assigned to an EPICS team of about 15–30 students. Membership on EPICS teams typically lasts through each student's freshman year, but students may elect to remain on their team for longer. After applying to EPICS program in May 2018, I was placed in the Delphi Community Elementary School, or DCES, team for the fall 2018 semester.

Figure 1 (banner image, above). Purdue EPICS students visiting DCES, studying the space and speaking with the partner.

DCES first reached out to Purdue during the spring and summer of 2018 about developing some underused spaces in their school. Purdue developed a partnership through our project partner Addie Marvin, a science teacher and Project Lead the Way (PLTW) coordinator at DCES. She explained that they had three spaces within their school that were underutilized and in need of improvements: an open library area, an unused classroom, and an interior courtyard. The Purdue EPICS program proposed a partnership with the school to have university students develop these spaces on behalf of the school to enable them to better serve the elementary students and the broader Delphi, Indiana, community. The team was subdivided into projects for each DCES space slotted for development: the library area (which came to be known as the Makerspace Project), the classroom (which came to be known as the 21st Century Classroom Project), and the courtyard. My project, the courtyard, posed a unique opportunity to provide the community with an innovative outdoor learning space.

Upon beginning my membership in EPICS at the start of fall 2018, I had no prior knowledge of DCES or the background of the team. After the first day of the EPICS class, I was placed by our faculty advisor on the courtyard project and assigned as the design team leader.

ASSESSING THE COURTYARD

DCES is a school of about 500 elementary school children spanning first through fifth grades. Delphi, located about 20 miles northeast of Purdue's campus, is a relatively rural area and part of the extended Purdue and West Lafayette community. Fall 2018 marked the inaugural semester of the project and community partnership with DCES.

To prepare for the semester, we traveled to DCES as a team to examine the courtyard and discuss with the project partner their specific needs. The courtyard is located in the middle of DCES and is only accessible through the school. A few of the classrooms, notably Ms. Marvin's, open into the courtyard. In the courtyard are several concrete planters filled with dirt, where currently DCES plants crops and flowers throughout the year. While the courtyard was certainly crowded by what was already in the space, I was excited by what I saw as an opportunity to make the courtyard better by making the existing infrastructure and activities more interactive.

Ms. Marvin discussed her vision and concerns for the project. As PLTW coordinator, she envisioned having a science and STEM focus to the activities to be placed in

Figure 2. Aerial view of the DCES courtyard and the labeled subspaces.

the courtyard. She placed a heavy interest in safety and durability of any activities. The idea is for the activities to help make for a more interactive courtyard to supplement classroom instruction.

Assessing the courtyard, we divided the space into five subspaces, in order to make the improvements more manageable and regimented: the Northwest Planter, the Northeast Planter, the South Planter, the Picnic Area, and the South Walkway. The goal was to place one activity in each of these spaces, which would maximize the utility and improvement of the courtyard without scope creeping leading to a project without set goals and boundaries.

Working with my team, we boiled down the instructions and information from our project partner meeting at DCES into stakeholder needs so our decision making would consider who is affected by our project. The primary stakeholder is DCES teacher and project partner Addie Marvin. Our project would benefit the stakeholder by providing a new learning space for her students. Her primary concern is with the educational value of the space. The secondary stakeholder is the students

themselves. The project will benefit them by providing entertaining activities that are easy to understand and interact with.

Based on this information, we developed a set of project specifications by which we could measure our ability to fulfill and meet the expectations of the project partner and stakeholders. The activities should have a basis in STEM and be integrated within the DCES courtyard. Any tools, equipment, or devices used to accompany the activities must be durable such that they can have a lifespan of multiple years while being stored and used outside. The activities should be reusable and should not degrade with each use. The activities should be simple and intuitive at the education level of an elementary student such that the space can be used for student self-instruction with teacher supervision. The project is meant to be safe, with the activities causing no harm for operation, involving no heavy items (greater than 15 lbs.) or materials dangerous to the safety of a child, including sharp or loose objects.

IMPLEMENTED SOLUTIONS

Our goal was to develop one prototype activity for the fall 2018 semester and deliver the completed activity for the spring 2019 semester. To accomplish this, the team first brainstormed a list of possible design proposals based a broad-based study of existing STEM activities, then voting on the five that best suited the purpose of the courtyard development. Our short list comprised activities focused on insects, agriculture, outdoor construction, flight, and weather. All of these activities and solutions were proposed to the project partner to gain feedback and approval for further development of the proposal that best met her needs and desires for the space. On our advice, our partner approved the weather activity for further development in the fall 2018 semester; she was impressed by its potential for the development of strong observational skills in the children. We were initially nervous that these activities might be overly passive and therefore be less exciting and engaging. Our project partner assured us, though, that the activity was not necessarily passive but instead would be less physical and more observational. Due to the relatively low space requirements for the project, we decided to develop the activity for the northwest planter, as this was among the smallest subspaces in the courtyard.

While we were inspired by a few weather stations and devices, none integrated physical devices in an accessible way for elementary students such that it met the needs and specifications of the project partner. Therefore,

we set out to design a prototype to integrate weather concepts and devices that are at the education and comprehension level of elementary students. Accordingly, we settled on measuring wind speed using an anemometer, wind direction with a weather vane, temperature with a thermometer, air pressure with a barometer, and rainfall with a rain gauge.

To more closely integrate these devices, we housed and mounted them on one rectangular prism shape. This internal structure was formed by a skeleton of treated 2×4 wood, surrounded by walls of plywood. This structure, while simplistic in design, provided a sturdy frame to house the weather devices that fulfills the durability and lifespan specifications of the DCES project. A rectangular prism design also provided significant flexibility with how and where weather devices could be mounted. The weather vane and anemometer, which require an unobstructed airspace for accurate measurement, were placed on the top horizontal face of the prototype, while the barometer, thermometer, and rain gauge were hung from the vertical faces of the prototype. The structure is formed to not involve any loose materials or dangerous objects, and all the weather devices remain light enough to not pose any danger to student safety.

Figure 3. Solidworks schematic of the inner structure of the equipment prototype.

The devices that were too complicated or dangerous to build we instead purchased. These were the thermometer, barometer, and anemometer. However, the weather vane and rain gauge were both constructed by the EPICS team, as this enabled us to custom fit the devices to best integrate them in the prototype. Also, by creating our devices, we could make them larger and more visible, to make observation easier for a classroom of students. The weather vane was constructed using a custom-cut wooden arrow to point in the direction of wind, affixed to an unthreaded rod that pivoted freely as an axle around skateboard ball bearings. The rain gauge was constructed as a large, clear plexiglass rectangular prism, taller than it is wide. The prism has five sides, with the top face removed to allow rain to enter, and the fixed sides held together using clear caulk along each edge to ensure no obstruction of the viewing of the water height. While we still believe that constructing some of our own measurement devices was the best path forward for the activity, this process posed several challenges. In hindsight, the problems we faced could have been predicted. When constructing the rain gauge, it proved exceptionally difficult to epoxy the sides of the rain barrel together at perfect 90-degree angles, as the sides would often fall when drying. While large-scale manufacturers typically have custom-fit rigs that make this task easier, we were forced to mimic this with less technical means, using wood blocks to align the acrylic sides of the rain gauge in place during drying. In addition, we found it difficult to attach the arrow to the axle of the weather vane. To

solve this, we used a plastic strap screwed to the arrow to connect the arrow to the axle, using the tension of the plastic to keep the arrow in place. This seemed to work well at the time but left us uneasy as we delivered the device prototype for testing.

Fulfilling the educational potential of this activity was an important part of developing our solution for DCES. To accomplish this, we drew influence from instructional curriculum practices and developed a series of lesson plans to supplement the weather station. Each lesson plan involved four components: learning objective, description, materials, and procedure. These were designed to give a detailed outline of both the educational value of each lesson and the steps to perform it. Besides lesson plans teaching how to use each weather device, there were three additional lesson plans provided. The first activity, the weather report, teaches students observation and note-taking skills by tracking and recording weather patterns over time. The second, the snow observation, combines measurements of temperature and snowfall by using the thermometer and rain gauge respectively to teach relationships between snow and temperature. The third activity, the snowball capsule, involves using the thermometer and location of the prototype in the courtyard to introduce concepts of thermodynamics by using household materials to insulate a snowball. To complete our documentation, we also produced a weather station user manual. This manual contained instructions for use, troubleshooting guidelines, and calibration instructions

Figure 4. Closeup photo of the weather vane arrow and attachment.

Figure 5. Photo of the rain gauge as delivered.

(as required) for the devices in the prototype. Delivering this documentation along with the prototype helped to tie the activity closer to the required specifications. And while the prototype itself inherently contains educational value in the use of weather devices, the supporting documentation gives a formal grounding of these devices in science and STEM instruction, an important specification of the project.

After completing the prototype at the end of the fall 2018 semester, the DCES EPICS team delivered the prototype for field user testing in the spring 2019 semester. This enabled us to see how successful our activity was as used by the project partner and how potentially we would need to change with the prototype. While we felt that the prototype was successful, the opportunity to have this review and trial period was invaluable in ensuring that DCES received the best possible product.

During spring 2019, Ms. Marvin had the opportunity to use the prototype and provided some feedback. While inclement weather plagued the region throughout the start of the semester, there were still opportunities for the students to go into the courtyard and use the weather activity. On these occasions, students were interested and engaged in the prototype, especially the anemometer. However, the rain gauge could use an integrated

Figure 6. Completed and assembled prototype.

measurement system to increase its utility, rather than having to find an external meter stick or ruler placed alongside the rain gauge. Additionally, the weather vane unfortunately does not remain durable under high winds and could use improvements and reinforcements to make it sturdier in inclement weather. Neither of these concerns is necessarily surprising. As previously mentioned, the weather vane had been particularly difficult to complete, making its flaws predictable. In addition,

it is intuitive that the rain gauge would need a measurement device.

With these two comments in mind, we set out to complete adjustments to the prototype to complete the detailed design phase of the project and officially deliver the project. First, we set out to tackle the stability issues with the weather vane. To solve this problem, we decided to recut an arrow for the weather vane, which we then drilled a hole halfway through the vertical length of the arrow in to allow for the arrow to spin freely on the axle while remaining upright on the strength of the wood. Second, we integrated a measuring system to the rain gauge. To accomplish this accurately and effectively, we took one meterstick and one yardstick and nailed them to the walls of the weather station on either side of the rain gauge aligned with the bottom of the gauge. With these two adjustments, we officially delivered the project to the partner and filed out the EPICS documentation to this effect.

COMMUNITY IMPACT

We view this project as a success. We measure this in two ways. By delivering the weather station, we fulfilled our goal to deliver a project for the courtyard by the close of the spring 2019 semester. A second, more qualitative metric of our project's success is in terms of the impact that it has on the stakeholders: the DCES teachers and students. Ms. Marvin ultimately indicated that she was happy with the project and had used the weather station multiple times with success. We believe this second metric of success is useful when assessing the community impact. Project delivery and maintenance conditions are dependent on stakeholder and customer satisfaction with our final product. Viewed through the lens of the goals of EPICS, service is about those you serve, and the opinions of those you serve should be placed before your own self-imposed goals.

We believe this project will have a significant impact on DCES. Ms. Marvin indicated that throughout the time that the weather station was in the courtyard, the students remained interested in the station, frequently asking questions about the project. The demonstrated student interaction in the courtyard addresses both stakeholder primary goals. At the surface, students being engaged in the project clearly shows the weather station as maintaining student interest and fulfilling the student stakeholder need of having an entertaining project. The students asking questions about the project demonstrates a student interest in the educational concepts of weather and climate. This curiosity aspect of student interest, in

conjunction with the value of the weather station as a physical instructional implement (see the Instructional Impact section below), gives it educational merit and fulfills the instructor stakeholder interest in providing a new learning space. Fulfilling these needs provides tangible benefits, beyond the formal engineering contextualization of the design process. When students visit the courtyard, there will now be an activity there for them to interact with and learn about. Weather devices, from thermometers to anemometers, provide a similarly deep context of the ideas of weather. Having been both an educator and a student, I find the mutualistic relationship of an engaged student makes the task of educating the student easier and more effective. Further, our project partner had indicated that if there were more activities in place in the courtyard, other teachers would be more likely to use it. Therefore, there would also be a greater student presence in the courtyard, prompted by our weather station. The weather station serves as an anchor for further classroom activities and school population interaction with the courtyard.

Being the inaugural semester working with this project partner, both DCES and Purdue experienced a moderate learning curve for understanding how to best collaborate with each other. This fact was compounded by the fact that nearly all members of the DCES EPICS team, including myself, were freshmen, and all were first-time EPICS participants. However, while none of us had any initial or prior preparation to work with the partner, we developed an effective communication protocol as time moved on. One member of the DCES EPICS team was appointed as the project partner liaison, and any time that a correspondence needed to be communicated, I would contact the project partner liaison and have her forward that message to the project partner. This ensured that there was one centralized point of contact between Purdue and DCES, which minimized the possibility of miscommunication. As design lead I made a consistent effort to send emails regularly updating the project partner with our progress. Informing the project partner of important or notable construction, documentation, and testing milestones provided the opportunity for feedback and confirmation that the project partner's needs and requirements were being fulfilled by the progress of the courtyard team. These steps led to an overall effective working relationship between DCES and the EPICS team.

In the future, the maintenance of this project and the production of additional projects for the remaining areas of the courtyard will be undertaken by future members of the DCES EPICS team. While the weather station is designed to last multiple years, continuing to solve

problems as they happen will help to extend the lifetime of the weather station and ensure it stays in use. This continued relationship can expand in depth and breadth in the courtyard. If the future EPICS teams desire to further build out the delivered weather station, they may provide an even deeper and more thorough educational value to the project, through both physical implements and instructional curricula. Alternatively, EPICS students may hope to develop additional projects for the courtyard, such as those conceptualized but not chosen at the start of the fall 2018 semester. These would expand on the stakeholder benefits in a similar way, but with a more diverse set of topics. By permitting learning about agriculture, insects, flight, and construction, the courtyard would attempt to cover all bases on student interests, so even those who are not engaged by the weather station would find a STEM topic and project where they could be entertained by the outdoor learning space. I hope that the progress that my team has completed these two semesters can continue to be sustained in the future, with the community benefit carried forward by subsequent EPICS teams.

STUDENT IMPACT

Having the opportunity to work in service-oriented engineering through EPICS was an invaluable experience for which I am incredibly grateful. My takeaways from my experience in EPICS range from interpersonal to administrative to engineering and career oriented.

Perhaps the most substantive and tangible lessons I have learned involve engineering disciplines and practices. It was not until the EPICS program that I truly understood how an engineer approaches problems. I had always been told by teachers, counselors, and other adults that engineering was a mindset. EPICS taught me this mindset. By following a set design process to complete our projects, I garnered a greater sense for human-centered design and how to be more conscious of the end user in the design decisions made. While I had participated in group projects before, few had been as extensive, as long-running, and as involved as the EPICS program. My teammates were some of the first people I met at Purdue, and we grew incredibly close over the course of the year. During the hours spent both in and out of the EPICS lab and class, I made a special effort to develop personal conversations into productive meetings. This helped keep our dialogues open. I noticed that at the start of the year, team members were often quiet and did not often speak up to add contributions to group discussions. However, as we became more comfortable with each other and developed our friendships, collaboration and contribution of opinions increased in the EPICS-oriented discussions.

Figure 7. Fall 2018 EPICS team at DCES.

Notably, this was the first major opportunity I had to interact for long periods of time with peers from outside the United States. While I was born in Chicago, Illinois, during my more formative middle and high school years I lived in northwest Indiana, the latter significantly less diverse than the former. Meeting my EPICS team was thus an eye-opening experience, with one student from China and another from Thailand. I knew how daunting an experience starting college was, and beginning that experience in a new country could only be even more so. I worked hard to be welcoming and accommodating, becoming friends with these teammates. Communication between new people is always challenging, especially so when there is a language barrier present. While I usually speak in a manner heavily laced with euphemisms, I made special effort in EPICS conversations to explain the meaning of such phrases to ensure that I more effectively communicated with my international student peers. In addition, I made a special effort to pronounce the names of my peers correctly. It took practice to master saying names in languages I do not speak, but I made sure for the first few weeks to confirm that I was using the exact, proper pronunciation. While it is a small detail, it is a meaningful one that goes a long way toward making people feel valued.

As design lead of the DCES courtyard team, my responsibilities extended beyond my individual contributions. As one of my most meaningful major collaborative projects where I had a leadership role, this was a great opportunity to hone my management skills. While I am not naturally an incredibly regimented person, the EPICS experience taught me discipline in remaining organized and scheduled to complete the tasks of the semesters. For example, I used a semester plan and Gantt chart alongside my personal calendar to maintain deadlines for the

project to ensure that the project and interim goals were completed on time. In addition, frequent communication with the other teammates about deadlines ensured these deadlines were met. Additionally, one of the other tools I used as a supervisor to complete the project was to allocate responsibilities to each member of the team. This was successful by being able to leverage the strengths of the individual team members to collaborate on the bigger picture. For example, one member who was proficient in Solidworks was assigned to transcribing the specifics of the schematics, while another member who had worked in a machine shop was assigned to constructing the prototype. This maximized the productivity of the team.

Perhaps the most relevant effect on my college career was how the EPICS experience influenced my engineering trajectory. I had begun with a desire to pursue civil engineering, but my positive experience with service-oriented engineering led to my push to pursue the more holistic aspects of engineering. Specifically, I intend to study civil engineering with an environmental concentration. This focus will give me the knowledge and skillset to design structures sustainably and minimize the ecological impact of human development. Given the pressing negative effects of climate change, I feel a strong desire to make an impact in a field where the challenges are evolving and the effects are wide reaching.

My experience then has been incredibly fruitful. The only way I might have improved it would have been to further engross myself in the experiences and personal lessons of the EPICS project.

INSTRUCTIONAL IMPACT

Perhaps the best lens to view the educational impact of this project is through the overlapping philosophies that drove its development: STEM and Project Lead the Way. STEM is an acronym standing for science, technology, engineering, and mathematics. As an instructional concept STEM can be incredibly vague, but it is increasingly being defined as the integration of its parts: using science, technology, engineering, and mathematics to solve real-world issues (Breiner, Harkness, Johnson, & Koehler, 2012). Project Lead the Way, known by the acronym PLTW, is not well known in the common discourse but is increasingly prevalent within schools. PLTW is a project-based curriculum program for K–12 engineering and technology education aimed at increasing interest in these disciplines. As of 2015, PLTW is present in over 6,500 schools, making it the largest pre-engineering education program in the United States (Hess, Sorge, & Feldhaus, 2016).

Our project makes a strong attempt at meeting these philosophies. Including all the different weather devices integrates different fields of STEM together in one place, placing more specialized meteorological tools like weather vanes and anemometers alongside more general science and mathematics tools like thermometers and rulers. Introducing the concept of weather in a practical, observable way presents a real-world issue into the courtyard, an important curriculum principle of PLTW education. By also implementing curriculum alongside the devices for the activity, we hope we can formalize the link to the educational basis of the project.

Examining the topic of this project can help further bring the positive impact of interactive learning space into context. Weather surrounds us, and its presence in society is ubiquitous, even for those of elementary age. Research has shown that while the Earth science aspects of weather are often intuitive to students, it is the physical properties of weather and its implications, including climate and climate change, that are often misunderstood (Henriques, 2002). Here, our project can be a tool to help address this specific deficiency. By providing a physical manifestation of weather observations, students can experience weather for themselves, and when used in conjunction over time, understand how the trends in weather relate to climate.

CONCLUSIONS

My time as the design lead of the DCES EPICS program has been incredibly rewarding. Over my time in the project, our team developed and delivered a weather station for the DCES courtyard. By listening to the feedback and requirements of the project partner, we feel we have developed an activity that supplements student science education and stimulates student interest in STEM with an engaging outdoor learning space. Personally, I have grown as a person, developing a stronger sense of interpersonal, productivity, and leadership skills. I believe that there is a strong, transferable educational value to the project, both to the project partner and the broader educational community. I am incredibly thankful for having had the opportunity to engage in service-oriented engineering, and would recommend the EPICS experience to all Purdue engineering students.

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ACKNOWLEDGEMENTS

I would like to give thanks to Addie Marvin of Delphi Community Elementary School for partnering with Purdue on this EPICS project. I would also like to thank Jorge Martinez, our EPICS advisor, for guiding us on

this project. Special thanks to my team members from these two semesters, who have become incredibly supportive friends. Finally, I thank Jennifer Bay and Marissa Tilden for their invaluable guidance in the writing and editing process.

Day, R. (2019). Weather Courtyard: Reflection on Interactive STEM Learning Spaces. *Purdue Journal of Service-Learning and International Engagement, 6*, 23–31. <https://doi.org/10.5703/1288284316981>