Creating Unique Transdisciplinary Project Based Learning Opportunities

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1. Introduction and Constraints

Teachers in traditional public schools around the country often struggle to implement effective Project Based Learning (PBL) focusing on Science Technology Engineering and Mathematics (STEM). Many of these educators attempting to employ these strategies soon encounter a long list of common obstacles that often stand in the way of sustainable practice. For over 10 years our transdisciplinary team (consisting of a Science, Math, ELA, Social Studies and Special Education teacher) at Pine Grove Middle School in East Syracuse, New York has managed to peel away many traditional constraints to create unique PBL to support STEM education. This initiative has not only opened up possibilities for other teams in our building, but has served as a template for several middle schools around the state to provide students with innovative learning opportunities. It is important to note that our administrative culture fosters a permission to take risks which allows teachers to experiment with best practices.

Many educators make an honest effort to incorporate some degree of project based learning opportunities in the classroom, but have reported encountering similar constraints that threaten sustainability. One of the seemingly most insurmountable of these is lack of time (Cingtang et al, 2018) and the accountability to State curriculum (Thomas, 2000). When constantly looking to squeeze every last drop out of class time to finish the state mandated curriculum, there ends up being very little left for things that are “extra” no matter how meaningful. Teachers often feel forced by these constraints to make decisions that are not necessarily in the best interest of students causing best practice to fall by the wayside. However, it is important to recognize that student feedback suggests immersion in engaging PBL and the design processes can motivate them to learn difficult content better than mere repetitive practice. (Remijan, 2017) Reducing repetition through well constructed PBL may actually increase efficiency and in turn create more instructional time. Our 8th grade middle school team has made a concerted effort over the last several years to challenge these constraints and with our combined effort, shift the student experience toward one rich in STEM PBL through the use of transdisciplinary teaching, collaboration with STEM community partners, flexible scheduling and dynamic student groups.

2. Shifting from Silo to Team Mindset

School is inherently divided into silos. Whether it is by subject area or grade level, ability or need, period or room, students experience learning in isolation. Teachers often professionally adapt to these silos to become masters of their domain, building complex closed systems to serve students as they see fit. Many of these teachers provide outstanding learning opportunities for their students in specific subject areas based on years of empirical knowledge gained through thousands of interactions with students.

As a parent of middle school age students, one can experience the girth of effort teachers put into organizing their learning systems first hand. The stack of parent letters handed out at the beginning of each school year often carefully outlines the course syllabi, materials, grading procedures, policies, apps, contact info, etc. in extreme detail. From the teacher (and often administrative) standpoint, this is a testament of a rigorous, high quality, organized classroom, assuring parents that their children are in capable hands. However, through the parent lens, this can be a bit overwhelming. Imagine a parent with two or three school age students reading and signing 10-15 of these dense documents on the first night of school. Couple this with the fact that these parents are most likely not educators themselves and may only be interested in contact information or a materials list. As a parent and educator, I even found *myself* bypassing the sea of rich information to simply find the signature page. Moreover, these well intendented and often required pieces of communication can go so far as to suggest a lack of coordination or systemic inefficiency to many working in the private sector. In this case they actually serve counterproductively to their original purpose. Considering this, imagine the student experience as they travel through several different systems each day. Each one may be of the highest quality, but the whole package may lose continuity, undermining the individual intent, providing a haphazard experience for students.

Inspired by a learning tour of exemplary STEM schools, the Metro School in Columbus, OH and Lake Travis High School outside Austin, Texas, a small conversation began regarding what instruction could look like. These two high schools were very different from our middle school in East Syracuse, NY. However, our commonality was the willingness to look at innovative ways to create unique learning opportunities for students. Within a few months of our return, the conversation reached a critical mass between open minded teachers assessembled to investigate change. As a pilot team, we started by looking at the continuity of the student experience both in systems and content. We examined each of our courses and searched for commonality in structure. Where similar elements presented themselves, we exploited them, deconstructing our silos and synthesized a new system composed of the best aspects of each. We also combed content for overlapping themes, realigning our units to set the stage for transdisciplinary instruction, not just between math and science, but all subject areas to create a more coherent package for students. One of the most difficult parts of this process was coming to the realization as an educator that some of the things that we do in the classroom are not necessarily BEST practice… they are simply GOOD practice.

Our first step was to hone in on content overlap, searching for places that concepts, language and skills could be aligned. Our transdisciplinary team consisting of a science, social studies, math, ELA and special education teacher each divided the units we teach across several Post-its. We created a large white board chart with our content headings across the top and affixed units in our respective columns in the order in which they were traditionally taught. Each teacher, then, took a turn giving a 30 second synopsis for every unit to convey the gist to the group. It was striking that teachers could teach so closely with colleagues for years and still have no idea what was actually being taught, driving home the point that we often teach in such isolation. This conversation was immediately fruitful. The sequence of Post-its soon began to shift to allow for lateral alignment of skills and concepts. As an example, a science unit on Light and Optics shifted to be taught concurrently with a math Transformations unit.

Students would be using mirrors and lenses in the science lab to create reflected, inverted and magnified images while graphing reflections, dilations and inversions in math class. Process skills quickly identified themselves also as commonalities between our subject areas. Making observations and inferences, supporting claims with evidence and using common language such describing velocity as a rate and identifying it in terms of slope on a graph are just a few opportunities that arose in this Post-it analysis of our courses.

3. Looking at Time, Space and Student Grouping Differently

Teachers often find themselves rushing to get through whatever curriculum they are teaching and rarely find the time to dedicate to fully integrated STEM experiences. This can make it difficult for them to imagine adding project-based units to their otherwise full planning calendar. Our team has recognized this obstacle as a formidable foe. A more efficient use of time, space and student grouping needed to be developed to maximize the school day, allowing the INSTRUCTION TO DRIVE THE TIME FRAME rather than having time dictate the instruction as so often is the case. Through analysis of our existing schedule, we quickly identified inefficiencies in roster configuration and redundancy, unlocking dozens of opportunities to flex within the confines of a traditionally built and scheduled middle school with little impact on the master schedule.

Many teachers have expressed that they used to do more project-based STEM or transdisciplinary lessons in the past and actually find themselves moving away from it due to time constraints. This is a difficult reality to face and the question needs to be asked: “If project based learning is so good for students, why are we creating situations that move us away from it?”

One of the largest contributors to this feeling of being “Crunched” is the way that time is structured in a traditional middle school, a long train of periods or blocks consistently drone on in succession. Teachers are relentlessly bound by the clock, planning 40 or 50 minute lessons at a shot. The process often plays out like this: A teacher has 40 minutes to work with. He or she has an activity that will take 25 minutes and a bell ringer that takes five. That leaves 10 minutes to close and assess the lesson. That is actually a pretty good scenario and usually works well. However, teachers often find themselves in the following situation: A teacher has 40 minutes. If he or she has the students pre-read the lab for homework, they should be able to collect data and graph results. Students then can finish “whatever” they do not get to for homework. A lot of times the “whatever” in actuality is the most essential STEM component. The analysis, conclusions, extensions and applications can become trivialised after thoughts rendering the lab void of its true intent. In rare cases the class can be too long for what teachers need to accomplish. For example: A teacher has a quiz that will take students about 30 minutes. That leaves students with 10 minutes of downtime, the teacher often has to fill non-essential activities to bridge these gaps and hesitates to start a new concept. Considering this, it is safe to propose that many teachers are functioning in a framework that forces time to drive instruction rather than allowing instruction to dictate time.

Our team recognized this obstacle as a formidable foe. A more efficient use of time, space and student grouping needed to be developed to maximize the school day. Luckily, our school district's middle school was front-loaded for some flexibility due to the fact that it was already divided into grade-level teams. For those unfamiliar, teaming is an educational model that has been around for several decades. Infact, our original middle school building that opened in 1969 was constructed to accommodate middle school teams. Our team has 96 students and between five and seven adults depending on student needs for that school year. Our Math, Science, Social Studies, English and Special Education teachers all teach the same 96 students over the course of the same periods that we are “on.” When students are off team, they are at “specials” such as physical education, technology, art, etc. (See Figure Below)

It is through this lens that our team saw the opportunity to use time, space and student groupings more creatively. Our first undertaking was to simply look at the day differently. Rather than viewing our schedule as teaching periods 1, 2, 6, 7 and 8 in a tradition class configuration we planned for the team as a whole with two class sessions, an 83 minute AM session (actually periods 1 and 2 +3 minutes passing time) and a 126 minute PM session (actually periods 6, 7 and 8 +6 minutes passing time) . With full autonomy for those two blocks of time, opportunities quickly presented themselves.

Master Schedule		Available	Team Utilization
1	Science	On TEAM	83 Minute Session 96 students 6 Teachers (+ Specialists) 5 Classrooms (+Available Spaces)
2	Writing	On TEAM	
3	Art		
4	Physical Education		
5	Foreign Language		
6	Math	On TEAM	126 Minute Session 96 students 6 Teachers (+ Specialists) 5 Classrooms (+Available Spaces)
7	Literature	On TEAM	
8	SocialStudies	On TEAM	

Rather than being completely dictated by the building wide schedule, the teachers on the team could configure class duration based on the time needed for instruction. The options available transformed from traditional 40 minute periods when needed to 80 minute blocks, or even 20 minute breakout sessions, that could be balanced to happen concurrently on a daily basis. The focus of team planning took a fundamental shift toward configuring our time to match the instruction that needed to take place. This conversation also set the stage for more creative discussions about constructing larger blocks of time by utilizing the 126 minute session at the end of the day or using the entire 209 minutes available to us for STEM project-based learning opportunities. Class size and configuration was now directly under the team's control. We could traditionally group our students into 4 sections of 24, but other options were available as the need arose. Common iterations of our traditional groups began to be utilized, including 8 sections of 12, 2 sections of 48 and 1 large group of 96. Yet again, we found that many of these groups of different sizes could meet simultaneously if balanced correctly. This not only allowed for students to work in different combinations, but created situations for teachers to teach in new ways.

By manipulating class size and duration, teachers from different subject areas could be available to co-teach transdisciplinary lessons. It is one thing to look for content overlap on paper. It is another to identify it in the field while you are teaching. One of the most powerful strategies in the quest for creating common student experience was consistently being present as a teacher in our colleague's class. As educators, we have very few opportunities to play a functional role in each other's classrooms. We found that by creating co-teaching situations for teachers of different subject areas to teach together, opportunities for content and process skill overlap were truly limitless. Referencing the example of concurrently teaching Optics and Transformations, we quickly came to the conclusion that the science unit could be completely enveloped by the math unit and co-taught by both to provide a seamless transdisciplinary experience for our students.

The large group of 96 could be used to deliver direct instruction or show a demonstration that served as a common experience for the entire team. All teachers could play a role, discussing through the lens of their specific subject area in later breakout sessions. This ability to meet as a large group proved to have other benefits as well, including giving our students a sense of identity by allowing us to set up a weekly morning meeting during which we could develop a team culture that embraces communication and collaboration, cornerstones of STEM PBL. Logistically, prudent use of the 96 student venue often created more instructional minutes available in the day by allowing one teacher to deliver instruction to all students in a short period of time and be available for additional contact minutes through the remainder of the day.

Students could be instantaneously configured by the team into groups that best suit their needs with a specific skill. Our team usually chose to keep our students in well-balanced heterogeneous groups configured in such a way that our special education teacher and teaching assistants could access students at an appropriate time. These groups were then rotated throughout the year to allow students on the team to work with as many different types of learners as possible and to maximize student productivity based on social behaviors. As needed, the team easily flexed groups to create homogeneous groupings based on data collected regarding specific skills providing a venue for targeted differentiated instruction and intervention.

This type of flexible scheduling and student grouping also required teachers to look at the spaces they occupy differently. Luckily, one of our team classrooms was separated by an accordion door that allowed it to open up into a double room. With this door open, we were easily able to create a space that could hold 48 students at tables and with carpet installed and furniture moved could accommodate the entire team sitting on the floor. We also had to make other decisions about non-instructional space, making some areas of the hall and stairwell places to accommodate small breakout groups. All in all, we were able to achieve this level of flexibility in time, space and student grouping all within the confines of a traditionally built and scheduled middle school with little impact on the master schedule. We also found that this dynamic model not only set the stage for innovative learning experiences, but also helped to solve many of the time constraints experienced by teachers. This discovered autonomy provided the infrastructure to support unique transdisciplinary STEM based instruction.

4. Infusion of STEM Community Partnerships

By reconfiguring a group of teachers to share common rosters of students and simply shifting periods so that these classes were being taught at the same time, teachers now had the autonomy to reimagine what the instructional day looks like. This new found flexibility to rearrange students into virtually any group size and time frame using the criterion of the task at hand, created the framework to support full implementation of transdisciplinary STEM based PBL in conjunction with our community partnerships.

Trying to forge meaningful relationships with STEM Partners that impact student learning can be a challenge. There is no shortage of teachers who would like to utilize members of the STEM community and partners who are willing to help. However, for many it is difficult to develop effective lessons that entail more than simply taking field trips or hosting guest speakers. Even these relatively traditional experiences can often be quite the logistical endeavor, either moving hundreds of students across town, hijacking a STEM industry partner for the entire day to talk to all of your classes, or having large assemblies that sometimes aren't as engaging for students as one would hope. Other common strategies involve larger companies or industry associations that have put time and resources into creating materials for students to connect them to STEM Industries. However, many classroom teachers find these activities to come off as canned and impersonal often lacking the scope and scale of a truly engaging activity.

The goal of our team became to systematically embed STEM community partners into project-based learning opportunities for students and move away from the model of guest speakers talking about their careers or field trips to STEM industry locations. The questions began to materialize: How do we use STEM partners as experts in the field to create meaningful experiences for students? How do we embed members of the STEM community into our projects? How do we use these resources as an authentic audience for assessment?

Our first experience using a STEM community partner in a more extensive way unfolded with Siemens Energy Corporation. Luckily, our administration had an existing relationship with Siemens as part of a building project in our district a few years prior so the connection had already been made. Upon our first meeting with representatives from Siemens, we found ourselves in a familiar conversation. Both parties wanted to do something to support STEM education, but no one had a clear idea as to what to do and the conversation kept circling back to guest speakers and field trips. The breakthrough in this discussion came when we all offered what skills we brought to the table. Teachers educate students in the classroom while engineers solve complex science problems. We shifted the focus to creating a situation that allowed each adult to function in that role, having our engineers design project scenarios, serve as expert resources in the field and provide an authentic audience for project assessment.

This gave rise to our first full scale team-wide project known as “The Energy Project.” We reconfigured our 96 students into a metropolitan area known as “Webuiltdis City.” Students lived in different neighborhoods and had jobs in the region, serving as government officials, members of the media, energy company employees, citizen activist groups, etc. Once our city was established, the scenario was explained. Due to our city’s recent population increase, it needed a new power plant to satisfy the needs of its citizens. Seven different energy companies would prepare proposals for powering the metropolitan area to be given at a town hall meeting in front of all community members at the end of the project. At that point, every community member would cast a vote awarding the energy company whose proposal resonated the most with their role as a stakeholder. Throughout the project all students would research solutions specific to their role designing facilities, raising objections, voicing support or enforcing codes to spin the final vote.

The engineers from Siemens played an interesting role in this project design on a few levels. Initially, in the planning phase, they helped to establish how the energy companies should be configured and what technologies should be focussed on. In later phases, specific engineers depending on their areas of expertise, met with different energy company employees focusing on the same technology serving as a content resource. Because the students had already done extensive research on the energy source, they were able to ask very targeted questions that would not necessarily be answerable by a regular classroom teacher, fully utilizing our STEM community members in an impactful way. After meeting with energy companies, the engineers also made the rounds and met with government officials, activist groups and the media to answer any additional questions that the students may have encountered in their research. In addition to their involvement with the setup and research portion of the project, our partners from Siemens were also present at the final town hall meeting to provide feedback as to the quality of the student presentations, giving students an authentic audience for their work.

The success our team had with this flexible format for project-based learning, was used to construct similar projects using a variety of STEM community partners. NASA's Jet Propulsion Laboratory in Pasadena, California partnered with us extensively for our team's “Mars Rover Project” the following year. Here, we had no pre-existing relationship so we were curious to see how involved an unfamiliar party would be willing to get. A quick trip to nasa.gov and one email yielded a STEM community partner that has lasted for several years. A representative from NASA responded within 24 hours stating that he would love to be a part of any project and through the support of this partnership, a project was created that gave students a national audience. Students used Lego robotics kits to simulate a Mars Landing in conjunction with MLS ROVER Curiosity. Our NASA contact not only assisted in the design of the project, but via video conference, helped to roll out the challenge and provide support to student engineers along the way. When it came time for our ROVERs to land on Mars, he helped to support our landing event through social media, bringing an authentic audience to the final product, further raising the stakes for our students. In the past 8 years this project has flourished and the scenario will be evolving to include the Current Mars ROVER 2020, Perseverance.

A unique relationship has also developed with a local architectural firm that our school district has used for building projects. King & King has been called upon several times to enhance project-based learning experiences in different ways. For example, upon visiting a local County Park undergoing shoreline revitalization, students could not help but notice that the visitor center was not expansive enough to accommodate our group of over a hundred. This authentic problem that the students encountered provided a great context for project-based learning. Modeling the architectural firm, our team set out to redesign the Onondaga Lake Visitor Center and representatives from King & King, provided logistical support along the way. Our partners served as the audience for final Visitor Center proposals which were given off campus at the architect offices, yet again providing our students with a layer of authenticity for STEM-PBL unattainable in a traditional inflexible setting.

4 PGL a Venue for Project Based Learning.

One of the most interesting products stumbled upon during our quest to create unique STEM based experiences for our students was Pine Grove Laboratories. Inspired by our work with NASA's Jet Propulsion Laboratory (JPL), "PGL is a science research facility established and maintained by Team 8 Orange at Pine Grove Middle School in East Syracuse, NY. PGL serves as the venue for trans-disciplinary project based learning in conjunction with our partners at Siemens, NASA's Jet Propulsion Laboratory, King + King Architects and the Technology Alliance of CNY."

Pine Grove Laboratories was an entity taken on by our team when we shut down the schedule for extended periods of time to complete engineering design challenges. Students were "fired" from class and hired into various non-overlapping interconnected roles. Once hired into a role, students often stayed in it for days, setting up shop in one of our team classrooms or breakout spaces. In the past, students have had to apply for roles, citing specific performance on previous projects. The projects were scaffolded in complexity over the course of the year and designed to give all students exposure to the different types of jobs available. We found that this “voice and choice” caused students to be vested in the project outcome and confident in the ways that they could contribute. Failure was very much an option. Though a rare occurrence students not successful in their given role may have had a formal intervention with peers that resulted in being let go from his or her position and having to reapply for any remaining jobs.

Our Mars Rover project was the first to utilize this new Pinegrove Laboratories model. Our STEM community partner at NASA's Jet Propulsion Laboratory in Pasadena, California introduced our design challenge scenario to the entire team via video conference. PGL: Aerospace Division had been chartered by NASA to follow in the footsteps of Mars Rover Curiosity. It was PGL’s task, to successfully deploy a Lego Rover remotely onto the surface of Mars at specific coordinates given to us by NASA. Once there, the ROVER would navigate to a rock sample of interest and take a variety of measurements. Students were placed into 96 non-overlapping roles ranging from entry, descent, and landing engineers to drive and instrument deployment programmers. A standard design brief format that students had encountered before to solve simpler scaffolded challenges was used to design all aspects of this mission. PGL scientists and engineers were responsible for the design, development and construction of all components of the mission including the mission sequence itself. Several students were hired as system integration specialists overseeing and coordinating each part of the sequence to make sure that all aspects could work together. Other students were hired as media specialists to cover the event pushing it out as an actual Mars landing via Twitter. Our contacts at NASA, as discussed previously, followed our work closely, enhancing our social media reach and providing information to our scientists and engineers as they worked. Pine Grove Laboratories ended this project with a landing event streamed live simultaneously from mission control and the surface of “Mars”. Students were isolated from the ROVER that they controlled remotely and experienced the same stress as NASA teams feel during actual Mars landings knowing that only teams with complete system integration would experience success Over the years PGL has expanded to include a nanotechnology division which simulates the fabrication of semiconductor wafers to make microchips as well as an energy division to develop efficient energy solutions for small cities.

It is important to note that prior to being hired by PGL, students had been introduced to the engineering and design process through a series of challenges that had been articulated to increase in complexity and followed the Engineering is Elementary design format with slight modification. After being presented with a design challenge in its simplest form, students were given an open forum to ask questions about materials, time frame and any other constraints often looking at what others have done in the past to solve similar problems. Once a clear picture of the task had been gathered, students imagined what possible solutions could look like, alone at first, then in a group brainstorming session. After groups discussed the pros and cons of the various designs, they developed and submitted a final plan to receive materials and move into the design process during which the solution was constructed, tested and improved. Though the individual components and content learned during the process may have been graded, final evaluation was usually relegated to the natural consequence of success or failure and was often accompanied by some sort of presentation of the solutions and results.

The structure of our Pine Grove Laboratories model allowed these projects to have a layer of interdependence, student voice and authenticity that would be difficult to harness without the flexible infrastructure our team had managed to construct.

Over the last several years our model has evolved. Schedules and student groupings have become more dynamic with the advent of technology that is able to produce targeted skill-based data for each student. Our framework is nimble and ready to adapt to new district initiatives and mandates as well as the natural fluctuations in the master schedule due to elements outside of our control. We have seen our physical space change to support our work. A cafeteria/auditorium and an oversized hallway that used to sit empty for a large portion of the day were now viewed as instructional spaces and accordion room dividers that had been closed for decades were once again open to allow for large group instruction. A recent building project has further enhanced our flexibility with additional rooms that can open up and multiple small group instruction areas. While every year brings new challenges, our team has managed to keep the problem solving mindset intact which, ultimately, is a cornerstone of STEM PBL.