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Making a “CASE” for STEM Education

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MAKING A "CASE" FOR STEM EDUCATION

Within the past decade, there has been a dramatic shift within our discipline. Programs and initiatives have diminished the idea of technological literacy and have moved from a comprehensive discipline to either very specific technical programs such as pre-engineering or CTE, to a contrasting vision of exploration learning such as Makerspaces or Fab Labs. The pressing question should be, what is most relevant and needed for today's students? Should we make all students engineers through programs like Project Lead The Way (PLTW), or should we make them skill specific through a Career and Technical Education (CTE) program such as welding, or should we let them learn technologies only relevant to what they need at the moment as they do in Makerspaces or Fab Labs? The following will review these questions and propose why today's high schools should provide a "Center of Applied STEM Education" or "CASE" to advance technological literacy, while supporting PLTW as well as Makerspace/Fab Lab concepts, and prepare students to enter CTE programs through comprehensive career exploration.

THE EXPANSION OF CTE AND THE DECLINE IN TECHNOLOGY & ENGINEERING EDUCATION

The constant transition of Career and Technical Education from Technology and Engineering Education is at an unsettling stance. The current view is Technology and Engineering Education, evolved from Technology Education, which came from the Industrial Arts era (Dugger, 2013). We could take the timeline further back to Pestalozzi, Comenius or even Victor Della-Vos, however, for this paper; most of the readers will remember the era of Industrial Arts. Industrial arts had a foundation in general education with a focus to provide a comprehensive curriculum to help build technologically literate students to enter a rapidly changing society. Career and Technical Education, previously Vocational Education (or Trade and Industrial Education), has been identifying their role in movements such as Tech-Prep, Regional Vocational Technical Schools (RVTS), and School-To-Work to provide skills for a student to enter the workforce after completing the program (Rogers, 1995). There has been a steady shift from strictly college readiness to career readiness as the focus of legislation targeted at careers (Gewertz, 2017). What has caused the country to move away from comprehensive Technology and Engineering Education programs, to swing its pendulum towards Career and Technical Education?

One item concerning the increase of popularity in Career and Technical Education is the identified 'skills-gap' our nation is facing. President Trump has made forward strides in the progression of Career and Technical Education. With the signing of the executive order to establish the Council for the American Worker, establishment of workforce development education committees, and signing the Strengthening Career and Technical Education for the 21st Century Act (Perkins V). Wolter and Ortiz state the 'skills-gap' is arguably the biggest hurdle facing the labor market, today (Wolter & Ortiz, 2018). With the unemployment rate at four percent, in 2018, there are still currently 6.6 million jobs left unfilled. With the focus on education, it helps refocus the mission of CTE to give students the specific skills needed to fill these open jobs, and close the gap even further. However, the extent of the skills gap should be assessed. The 6.6 million jobs described in by the Bureau of Labor Statistics', issued survey results from their previous Job Openings and Labor Turnover Survey (JOLTS). It states that these job openings are the result of: 3.2 million workers quitting their current jobs, 1.7 million workers losing their jobs as a result of a layoff or firing, and 0.3 million workers retiring or transferring to a different location within the same firm (Koc, 2018). It should also be noted 4.3 million of these jobs in the 6.6 million (65.15%), required at least a bachelor's degree to be considered for the job (Koc, 2018). The ability to educate for the bachelor's level goes above the current abilities of the public school sector. There are incentives for using the public school system to educate students, and give them the skill set needed to obtain jobs in post-secondary endeavors. One component of CTE programs in the secondary setting is to provide students with the opportunity to gain certifications. There still needs to be a necessary balance between CTE and Technology and Engineering Education. An argument in favor of Technology and Engineering Education, especially in the setting of a rural school community, is one teacher, who only teaches within the Construction pathway, meeting the needs of all students, rather than just an interested few? Not every student will want to become a carpenter, electrician, or plumber. Some may want to become graphic designers, videographers, welder, draftsman, or engineer.

PROJECT LEAD THE WAY AND THE INFLUENCE ON TECHNOLOGY AND ENGINEERING EDUCATION

With over 43 million in total revenue, PLTW is notable force in the discipline of Technology & Engineering. (Charity Navigator, 2018). This is in sharp contrast to the operating budget of the International Technology & Engineering Educator's Association, which is just over 1.5 million. The growth of PLTW has been significant since becoming one of, if not, the largest pre-engineering program in the United States. The program has many strengths to include getting students more interested in STEM subjects, in particular math and science. (Hess, Sorge, & Feldhaus, 2016) The presentation also noted students participating in PLTW were motivated to pursue and persist in STEM degrees; and PLTW's professional development increased teacher's confidence when implementing PLTW curriculum.

While the strengths of PLTW are notable, the Hess, Sorge and Feldhaus study also pointed out a few potential weaknesses. These include lack of empirical evidence student's math and science abilities increase as a result. Also noted is space limitations for implementing the program along with the cost associated with implementation, which could hinder some economically disadvantaged districts.

After observing student teachers in schools for over ten years where teachers have implemented PLTW, there are several personal notations regarding PLTW. (Observations by the author of this article) First, the teachers are usually very enthusiastic about the program and refer to themselves as PLTW teachers rather than Math, Science, or Technology teachers who happen to teach a PLTW curriculum. Secondly, many of the programs focus on the design aspects with outputs of the design and are limited to laser and 3d printing applications. Many of the programs lack comprehensive laboratories (or shops) to build projects. In some cases, teachers many not have the technical expertise to adequately teach machine/tool operation or in such environments, which could be problematic as a liability issue for districts. Third, like most classes, there are students fully engaged in the coursework while others may not have the interest. Lastly, the curriculum is very prescriptive, which is advantageous to those without any technical background, yet can be restrictive on going beyond the curriculum. It should be noted the author has only observed between 15 and 20 PLTW programs. Overall, PLTW is a very good program, but is part of an educational solution, not the entirety of the solution.

MAKERSPACE AND FAB LAB

To a lesser extent, the Maker Movement has been gaining traction worldwide over the past decade and schools have begun to implement Makerspaces. Makerspaces and Fab Labs are current "hot topics" in many districts, even though many do not truly understand what the spaces are or how to implement the spaces. Dale Daugherty, founder of Maker admitted, "If schools don't get the spirit of it, I don't think it will benefit them a whole lot" (Herold, 2016). The article notes bringing maker education might even be messy and uneven because the concept itself is "a highly squishy concept".

As Herold points out, a making refers to hands-on activities that support academic learning and promote experimentation, collaborations, and a can-do mindset. However, based on the article, educators use the term to describe a formal STEM curriculum, to project-based classrooms with bins of craft materials in the library. As a result, the article points out it is difficult to know how many schools have implemented the maker approach. There is no formal implementation of a Makerspace, it can be a defined classroom, or a resource are within a library. This is problematic for several reasons. Schools can put someone into the space who is not necessarily educated in building, programming, machining, etc. From a liability perspective, this could put the school and the teachers on a very slippery slope.

Fab Labs are similar to the Makerspaces in theory, in fact, the two organizations have paired up and use the terms together based on web site information. (School Fab Lab, 2018) According to the School Fab Lab, the program is now in over 1300 schools located in 109 different countries. The program has eight different stations to include: Digital Fabrication Machines, Virtual Reality, Drone Programming, Video Conferencing, Robotics and Drones, Game Design, Artificial Intelligence and Electronics.

DISCONNECTION WITHIN THE STATE

One issue in the disconnection between CTE, PLTW or Maker and TEE begins at the state level. There are cases in which representatives hired for offices, have little to no experience in the realm of Technology and Engineering Education or Career and Technical Education. This can have a harrowing effect on existing TEE programs across the nation. Without proper knowledge and promotion at the state level, programs can suffer closure, which in turn lowers the amount of professionals to enter available teaching positions. The pool of professionals actively debating teaching as a career, which includes technology, & engineering education issues is decreasing as a whole. (Picchi, 2018) Young people are not choosing education as a career for a number of reasons which include pay, the negative stigma placed on teaching, the press coverage of shootings, just to name a few. A 2017 report of 2015-2016 data indicated 2,106 universities produced 159,598 teachers, compared to 2,147 universities producing 217,506 only five years earlier, which is a 26.63% drop in graduates. (Title II Higher Education Act, 2017) One possible solution for TEE programs, would be political action via education departments, the importance of technology [and engineering] education being a required subject for all secondary students may develop (Volk, 1997). States, such as Maryland, Pennsylvania, and Missouri, have included Technology and Engineering Education in their state scopes for secondary education and requiring a course in this domain and others, such as Kansas, you cannot find any reference to on the state website. Having recognition as a discipline would inevitably help save the mission of Technology and Engineering Education programs nationwide and provide technological literacy to all students.

THE VALUE OF TECHNOLOGY & ENGINEERING EDUCATION

Before going further, the question of "is Technology & Engineering Education needed, is it a valid content area?" Due to the comprehensive nature of T&EE, as a content area it is critical. In 2018, Moye, Dugger, and Starkweather, in conjunction with the ITEEA, released results from a study called The Learning Better by Doing Project. The study provided insight to the importance (or value) in Technology & Engineering Education. In the United States, there have been several studies to help understand and modify the scope of education to reflect current views. Americans feel that taking technology and engineering classes and developing interpersonal skills are the two most important aspects of school quality (PDK, 2017). The results of the study were supportive in the findings that technology and engineering classrooms are determinant in students' success. The purpose of this study was to determine the extent to which U.S. public school elementary and secondary education science, technology, engineering, and mathematics (STEM) students were doing activities in their classrooms (Moye, Dugger, & Starkweather, 2018).

The results of the study found that technology and engineering classrooms are effectively meeting all three of the learning domains, as described by Bloom's Taxonomy. These domains included cognitive, affective, and psychomotor. Cognitively, technology and engineering lessons and activities not only engage students, but also easily applies an interdisciplinary approach. These lessons and activities help students in the integration and application of disciplines such as science, history, mathematics, and language arts. Affectively, these classrooms use activities that encourage students to use teamwork as an approach to solving problems. Teamwork involves building relationships and working with other people using a number of important skills and habits (ODEP, 2016). Technology and engineering students frequently work in teams, using engineering design processes to consider how they would solve real-world problems (Moye, Dugger, & Starkweather, 2018). Teamwork can help develop many important qualities in students, including higher self-esteem, promote student relationships within the classroom, and developing better social skills. Finally, Technology and engineering courses provide students with opportunities to use hands-on activities, exercising their creativity and problem-solving skills in effort to solve-real world problems (Moye, Dugger, & Starkweather, 2018). This is an important aspect in developing psychomotor skills in students.

CURRICULUM DRIVES FACILITIES

It is apparent, that larger schools with more student populations, access to more funding have more opportunities for students. These schools have the resources to have Career and

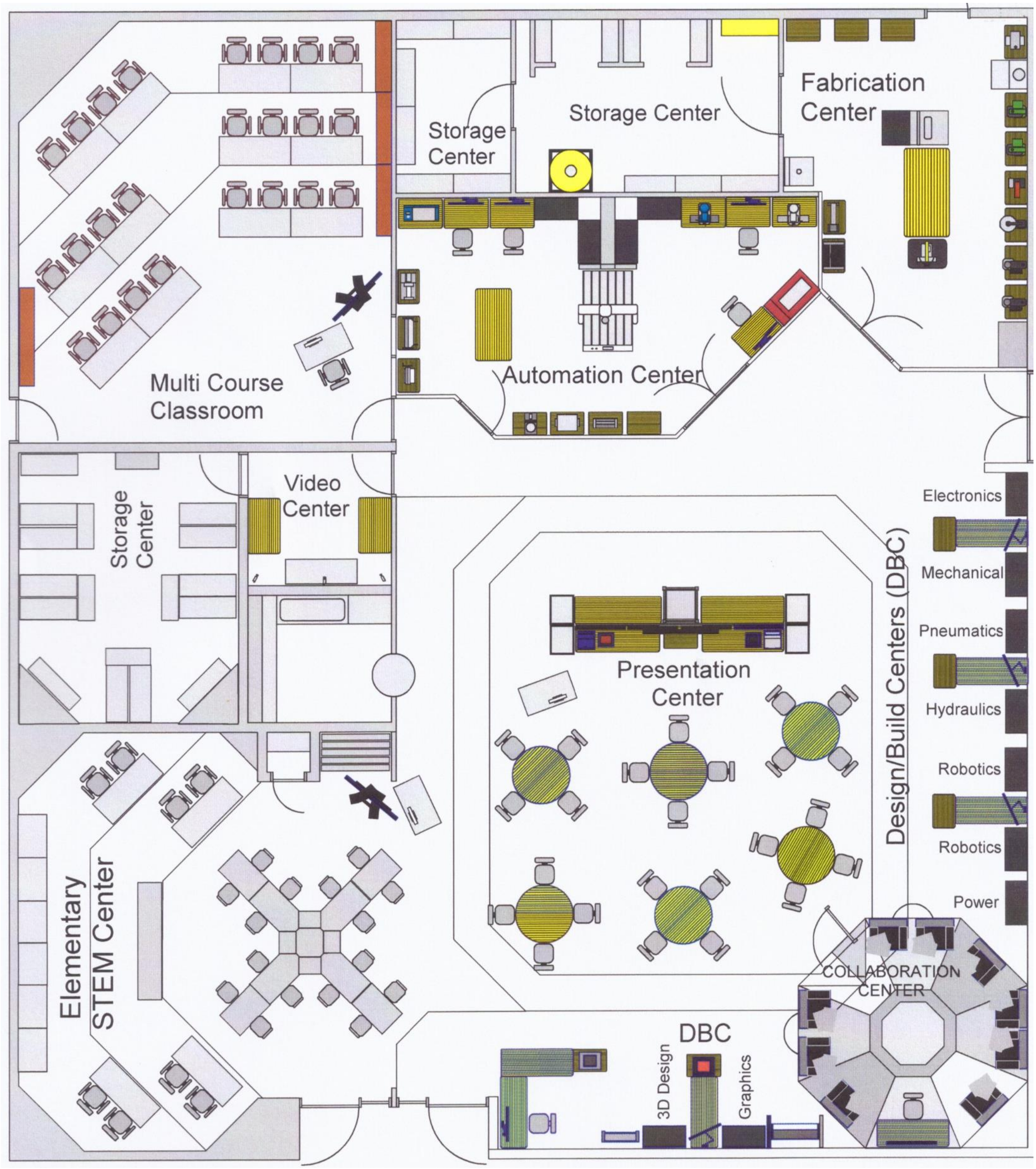
Technical Centers, they could have unit shops such as welding or woodworking, or curriculum based courses such as PLTW. Smaller schools usually have a more difficult time providing these opportunities for students due to restricted space, funding allocations and staffing issues. Michael Neden (DTE) often said, "Schools should assess their success on the number of options they provide students upon graduating from high school. If their options are limited, you have done them a disservice". For the purpose of this paper, the focus will be on the smaller school with one teacher.

On the following page, the floorplan for Pittsburg State University's Center of Applied STEM Education will be the foundational component for this paper. The center is designed to support a comprehensive, standards-based Technology & Engineering Education program. However, it would easily support a PLTW program, a Makerspace or Fab Lab as well as some unit type labs and the activities associate with them. The Center of Applied STEM Education has several centers to support technological literacy. These include the following areas.

- Presentation Center
- Collaboration Center
- Design Build Centers
- Fabrication Center
- Automation Center
- Communication Center
- Elementary STEM Education Center (for preservice elementary education majors)

Subsequent pages will explain each are in further detail. The author of this article created or captured all pictures contained in this paper. To look at a 360 degree virtual tour of the facility, Control + Click or enter the following address in your address bar. https://vizor.io/bmckay/technology-engineering-education-lab.

Pittsburg State Universities Center of Applied STEM Education



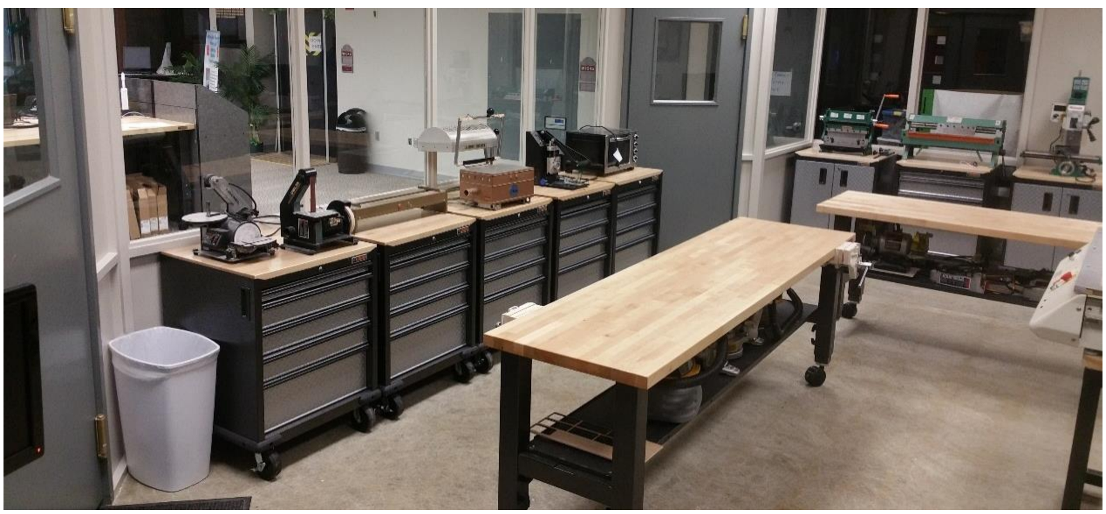
- PRESENTATION CENTER – the presentation center provides focal point for all instructional activities as well as giving the students a place to practice public speaking skills. Students need as many opportunities to present as possible as future educators. In a high school setting, this would provide a place for students to present projects and activities. The center has a 75 inch touch screen television, with full multimedia and sound capabilities.

- COLLABORATION CENTER – this center provides a quiet place away from the lab for students to work in larger groups of up to eight students. It is fully multimedia capable. If not being used as a collaboration room, students use the space to hang out or do homework, watch movies and use the Wii or Playstation.

- DESIGN BUILD CENTERS (DBC) – these four stations are the cornerstone of the CASE laboratory. Students develop group skill work on short and long-term projects. Each DBC has corresponding cabinets providing tools and supplies related to a specific technology. Cabinet are mobile and can be moved or loaded with other supplies and tools as needed. Currently, the cabinets hold 3D printing, robotics, electronic, fluid power, mechanical and small engines. Each of the small rolling cabinets top tow drawers are the same at each DBC eliminating the need for students to leave and get common tools. Each station also has a 32" monitor and computer with all necessary programs. Students can also hook up their laptops to the monitors. Each DBC has a camera located above each monitor, which projects to a corresponding monitor in the presentation center.

- FABRICATION CENTER – This center has tools necessary for drilling, cutting, sanding, and finishing. Every machine is on wheels providing for flexibility so they can be taken to schools for a mass production/assembly line project, moved to be more productive for certain classes or taken outside for construction projects. Tool panels are flexible (easily re-arranged), and are clearly marked allowing for immersion learning to take place at all times. Organization is the key to production and follows the 5S system of manufacturing.

- AUTOMATION CENTER – CNC operations as well as a laser engraver are the bookends of this space, combined with some metalworking and plastics machines. Students can design at any DBC or one of the computers or laptops available, then produce parts on



the CNC router, CNC metal lathe or CNC milling machine. Metal and plastic fabrication are also completed in this lab.

- COMMUNICATIONS/VIDEO CENTER – Digital imaging, photography, videography and live video production are housed in a 10' x 10' space thanks to flexible furniture and digital technology. When needing to edit video or manipulate digital images, the furniture is moved to the main lab area, leaving the green screen to create a very large digital studio, which would rival ESPN, CNN or any other full sized studio.

- ELEMENTARY STEM EDUCATION LAB – This classroom/lab is fully capable of teaching pre-service elementary education majors the benefits of integrating STEM into the elementary classroom. The lab has a 75" touchscreen television, as well as ample storage for stem kits and materials, which could be replicated in any school. During the spring 2018 semester, over 250 fourth grade elementary students experienced STEM education in the lab through an agreement with Pittsburg School District.

KEY ADVANTAGES/COMPONENTS TO THE CENTER OF APPLIED STEM LEARNING

- FLEXIBILITY – All furniture, machines and chairs are on wheels allowing for a very flexible educational environment. The laboratory can take on an entirely new look in a matter of minutes.
- COMPREHENSIVENESS – The laboratory is capable of anything, from problem solving, drafting/design, CNC, robotics, 3D printing, UAS (drones), printing, vinyl sign cutting, fabrication (metal, wood, plastics, earth materials), digital imaging, videography and more. Students get more experiences in all of these areas. The experiences allow the student to go into as much depth as they want to.
- ORGANIZATION – In order to move students through different classes. Equipment, tools and materials need to be clearly marked and organized.
- ADAPTABILITY – The CASE laboratory can morph from one type of program to another. One class could have communications, another could be PLTW, or possibly materials and processes, manufacturing or construction, just to name a few. The abilities of the lab are only restricted to the abilities of the Technology & Engineering teacher.

FURNITURE AND EQUIPMENT

It was important during the development of a CASE lab to maintain an "off the shelf" mentality. Cabinets come from local or regional distributors. PSU purchased the Gladiator cabinetry directly from Gladiator (https://www.gladiatorgarageworks.com), however, it is available for purchase from The Home Depot and other stores. Another brand considered was Sam's Club's Seville line (Figure 1), which had similar components to Gladiator, and was less expensive. In order to accomplish the pre-engineering look, the Gladiator steel tread plate design was ultimately selected for use in the CASE lab. Equipment, tools, machines, robotics, UAS systems, etc., ca be purchased from any vendor as long as it fits the flexibility requirement. Depending on the budget allotted, the value of the furniture, machines, tools and other items can vary greatly. (https://www.samsclub.com/sams/search/searchResults.jsp?searchTerm=seville&searchCategoryId=all),


Figure 1: Sam's Club Seville Cabinets

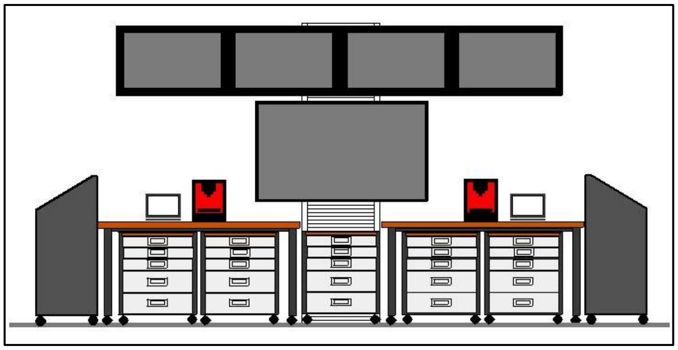
The total cost of renovation for the lab was approximately $160,000.00. This total included the cost of flooring (removal and installation). Pittsburg State University faculty solicited business and secured matching funding to complete the project. A simple listing of costs is included below.

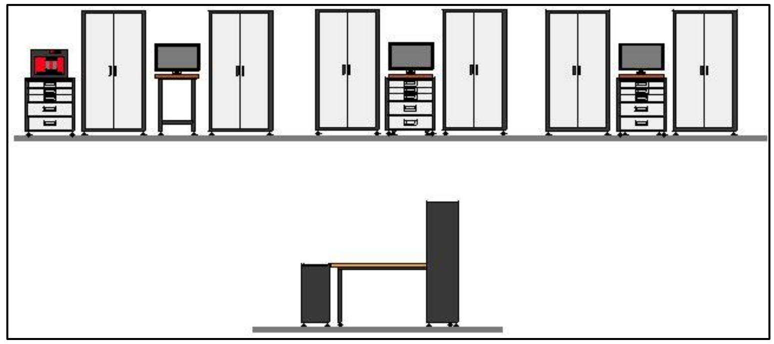
Flooring	$25.946.00
Furniture & Cabinetry	$44,464.00
Electronics/Software	$15,124.00
Equipment and Equipment Upgrades	$35,468.00
Classroom Materials	$31,654.00
Hand Tools and Benchtop Machines	$6,685.00
TOTAL	$159,341.00

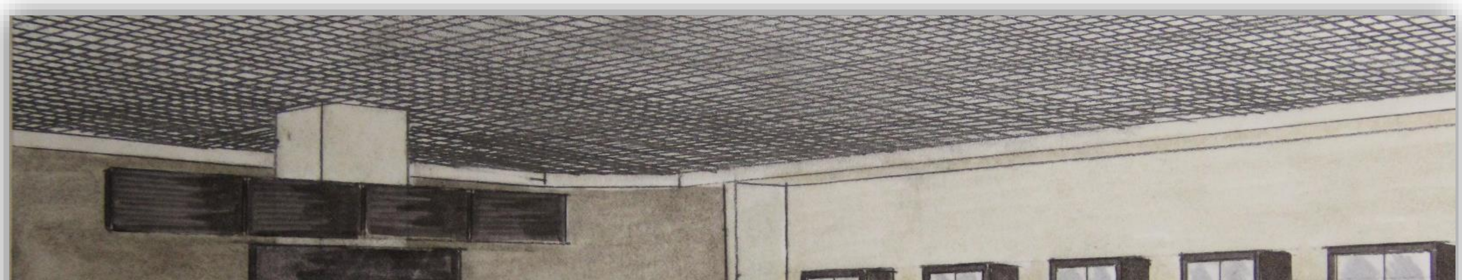
CONCLUSION

The purpose of this paper is to propose a laboratory capable of meeting the needs of the 21st century school system. The CASE laboratory will best serve the student population in a small school with one teacher. A CASE laboratory is capable of maximizing the opportunities for each student and gives them skills necessary to be technologically literate. Through proper lab design and management, a teacher does not have to offer either/or, but more!

Original concept drawings and a sketch of the lab before approval are shown below.







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