THESIS

CAREER TECHNICAL EDUCATION IN HIGH SCHOOL:

TEACHERS CREATE MORE RIGOROUS AND RELEVANT PROJECTS WHEN THEY CO-DESIGN PROJECTS WITH INDUSTRY PARTNERS

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Abstract:

This action research study sought to discover whether the level of rigor and relevance of student projects in high school career technical pathways could be improved through individual coaching of teachers on effective collaboration with industry partners to co-design projects. Coaching also included professional development on the elements of high-quality project-based learning, and in real time, use of a project design/management template, a rubric, and a guide for working with partners. Five career technical education teachers participated, including teachers in the fields of environmental science, engineering, and health professions. Coaching began with discussion of past projects these teachers had done to establish a baseline. Evaluations were based on a Buck Institute rubric on essential elements of project-based learning. After professional development on collaborative project design, observations of the teacher interacting with the partner were debriefed, and coaching continued as needed. Final projects were evaluated on the BIE rubric, and satisfaction with the project and collaboration process through interviews with the teacher and industry partner. The results of the study indicated that the intervention supported teachers' growth in the areas of project design and effective collaboration with an outside partner in the field of study. Projects were more rigorous and relevant as a result of the intervention. Results also underscore the need for continued professional development and coaching of teachers in this area. In particular, the study provided instructive examples of successes and struggles in the area of project negotiation, which can serve to deepen future professional development.

Background and Context

Career Technical Education began in California in 1967 with Regional Occupational Programs ("ROP".) At that time, Career Technical Education ("CTE") or ROP was seen as an alternative education track for students who were not planning to go on to college. In 1984, a different and more all-encompassing model of career technical education was adopted that envisioned students being exposed to and prepared in high school for all types of careers, including those requiring advanced education. This model was established by the California legislature and was called the California Partnership Academies ("CPA"s.) The California Partnership Academy model calls for integration of core courses such as math, science, English, and social studies, with the career technical course work. The teachers teach in a team to serve a cohort of students, essentially forming a small learning community. Moreover, the CPAs are not seen necessarily as an alternative to college, but as preparation for careers requiring a variety of post-secondary training or education, including college. (For a fuller description, history, and analysis of CPA's throughout California, see the Profiles of the California Partnership Academies website listed in Sources.)

As society has evolved technologically and innovatively, the number of careers or jobs that require only a high school education has dwindled, some estimates say to 12%, (Fleming, "Success in the New Economy") and they are generally low skilled and low paid jobs. The ROP and CPA models exist side-by-side today, with the number of ROPs generally on the decrease, as the California Department of Education and California legislation makes the shift away from an emphasis on the non-postsecondary, vocational track of the past ("voc ed.") Instead, programs are referred to as Career Technical Education programs, ("CTE,") in order to emphasize an

updated view of career education, one that acknowledges that most careers today require post-secondary certificates or degrees of some type. The message that CDE is promoting is college *and* career, rather than two separate alternatives. Increasingly, colleges are identifying career pathway programs and not just majors of study. (Carnevale, et al, 2017.) (California Community Colleges, 2018) The number of CTE programs in California high schools has been growing since 2011, mirroring a national trend. (Frey, Ed Source, 2014). The purpose of this statewide reform initiative was to address the problem of a high student dropout rate by connecting or contextualizing the learning in school to skills needed in today's careers through partnerships with career professionals.

The first two California Partnership Academies were formed in my District at one high school in 1995, and gradually teachers, without much district-level help or support, added to that number by applying for additional CPA grants in a variety of career sectors. As the 1990's closed, there were four CPA's in the District. By the time the Linked Learning Initiative began in the 2009-2010 school year, the School District had 14 CPA's, and decided to partner with Linked Learning to improve career pathways through professional development for all levels of district leadership. The Linked Learning Initiative identified the principles or "pillars" of Linked Learning as a main high school reform strategy, and our district adopted that also as their main reform strategy. The Pillars of Linked Learning are fourfold: rigorous academics made relevant through career pathways; technical skill development toward high skill, high wage employment; and work-based learning through industry sector-based opportunities such as speakers, project and curriculum advisors, job shadows, and internships.

The key is that the "Partnership" referred to by CPA language and the "Linked" in Linked Learning both refer to strong collaboration between industry sector professionals and educators. Each CPA or pathway is required to form an advisory board of career professionals from a broad spectrum of the career sector to advise on developments in the industry, suggest changes or updates to curriculum, and to connect teachers and students to work-based learning opportunities. For purposes of this study, the term "Pathways" refers to all career technical education programs with a sequenced course progression and an industry advisory board.

While the California Partnership Academies were formed to address the issue of struggling students in danger of dropping out, the model demonstrated success for all students, and was expanded to include all students interested, as long as at least 50% of incoming students are deemed "at risk" in terms of credit deficiency, truancy, low socio-economic status, homelessness, and challenges related to living in foster homes. In other words, students cannot be chosen or rejected due to a stellar or lackluster academic performance or behavioral pattern. The reform movement is about reaching all students with engaging career-focused curriculum, but with a mandate to include and embrace at-risk students and engaging them in relevant, hands-on learning as a means of motivation.

Stepping back briefly for a broader picture of the School District, before outlining the research action undertaken herein, the total comprehensive high school population is approximately 7,500 in six high schools. Four high schools range in size from 1200-1500, and two have a student population of approximately 900. Two of the six schools are nearly wall-to-wall pathways except for students who are limited by the need for specialized classes, predominantly in intensive English language instruction. The other schools range between a

quarter to half of students who are in pathways. As a district, the population of socio-economically disadvantaged students is approximately 70%, and English Language Learners comprise approximately 35%. That percentage increases respectively to as high as 94% and 38% in two high schools. In terms of race, four of the high schools could fairly be classified as diverse, with majority students of color, including African American, Latino, Asian, and White students in the mix. Two of the high schools are primarily made up of Latino and African American students. The demographics of the students in pathways correlate to those of their schools overall.

Currently approximately 60% of District high school students are enrolled in a pathway program. This includes four health pathways, four information technology pathways, three law, two engineering, two media, one performing arts production, an automotive repair pathway, and a welding and metal fabrication pathway. Thirteen of these 18 pathways are CPAs and include a team of core academic teachers who work collaboratively with the CTE teachers as a small learning community. The other six pathways were formed more recently under a different model; students take a 2-3 course sequence but are not cohorted in their other classes as a small learning community of students and teachers. This model allows for greater flexibility for sites and students, but may not result in the level of support needed for some students. Once the data is analyzed, individual schools may decide to voluntarily bring in a math or science teacher as part of a cohorted team voluntarily. This has already occurred at one high school with their engineering pathway.

Prior to the Linked Learning initiative, pathways operated mainly through a lead teacher communicating directly with the California Department of Education through annual reporting,

including narrative and student data submission. The report requires that industry partners and work-based learning activities are identified. With the advent of Linked Learning, more pathway-focused education was provided to administrators, both site and central office, and all levels of leadership were encouraged to attend conferences for sharing of ideas and to develop systems of accountability. Once pathways attained "certification," they were invited to come together to an advanced pathway workshop, where, for example, teachers learned about exemplary student projects and planned "senior defenses," (during which students demonstrate that they had met the stated pathway outcomes.) The pathways that demonstrated this readiness also came together to explore more intentional work with industry partners so that partners could offer students and teachers feedback on curriculum and projects. Gradually, this is becoming the norm in the District, and the work is supported and assisted through a College & Career Department.

By this school year, 2017-2018, the District is continuing its work within its own structures of support, and is no longer dependent on the Linked Learning initiative. The Office of College & Career supports and facilitates a monthly pathway leads and CTE teacher Community of Practice and a Principals Community of Practice focused on pathways. There are three full-time Coordinators in the College & Career Department, with one focused on successful pathways to college, including articulation and dual enrollment, as well as aligning with the work of community-based organizations focused on better college outcomes. Another College & Career Coordinator is focused on cultivating industry partnerships, creating well-functioning, purposeful advisory boards, and generally broadening partnerships for all aspects of work-based learning. The third Coordinator (the writer) works closely with the pathway teams to ensure they

have enough support and feedback to meet all of the elements of a high-quality pathway. In that regard, I collaborate closely with the employer partnership Coordinator (who joined the department in the last year) to ensure that the efforts between teachers and employer partners is effective and leveraged with identified learning goals.

As referred to above, Pathways are required to form an Advisory Board specific to their pathway, whose role is to advise and support the pathway teachers and students through various means, such as co-creating pathway outcomes (defined as what students will know and be able to do at each grade level), reviewing and advising on the relevance of curriculum units and projects, and to suggest study trips or speakers. (For several years, the expectation of the District has been that pathway teams create at least one such project at each grade level.) Part of the problem, as observed, is that most of the pathways have treated advisory board meetings as a "checkbox," a platform to merely present projects or units they are doing. Thus, in the absence of a request to do so from teachers, advisory board members have expressed to Central Office College & Career Coordinators a reluctance to supply constructive criticism of curriculum gaps or inadequate projects, particularly if they feel a project does not address relevant skill development needed to build a well-educated workforce in their sector. It has become apparent through discussions with these advisory partners, and through observation, that the quality of pathway projects, in terms of relevancy and rigor, is often deficient.

A concerted effort was taken to improve project quality three years ago, but without an emphasis on partner involvement. The District's Curriculum and Instruction Department (or Ed Services Department, as it is known), requested that the College & Career Department help to align pathway work to as vehicle to support the Common Core standards. At that time, an

organization called ConnectEd facilitated the opening professional development sessions for pathway teams, and provided a rubric for identifying high quality projects aligned to pathway outcomes and Common Core standards. As CPA pathway teams of teachers participated in these professional development sessions, Pathway team collaboration around academics and curriculum mapping improved, but there was wholesale rebellion against the mandate to use the software platform as a tool for uploading projects, aligning them with standards, and evaluating them according to vetted rubrics on the site. Surveys indicated the problem was mostly due to "platform overload." The ConnectEd Studios program introduction was simultaneous with a district-mandated use of Illuminate, a new Student Information System, and a new ordering software platform in the District. Several teachers were also being introduced to and trying out optional platforms such as Google Classroom. Two years ago, the Office of College and Career decided to borrow the best aspects of ConnectEd Studios project and curriculum mapping, without the mandate to use the platform. The pathway project rubric developed by ConnectEd to evaluate the rigor and relevance of projects was used in the next year's professional development, with guided activities to reintroduce and reinforce the concept of rigorous projects, sometimes referred to as "performance tasks" in order to place an emphasis on what students actually do or produce, but without the mandate to use the software platform. Principals also participated in a professional development led by ConnectEd so that they could work with their pathways in this regard. Although projects improved to some degree, and the same rubric along with professional development may continue to be a useful tool to increase rigor, it did not increase the relevance and rigor to the desired degree. However, there are indications based on

project comparisons, that industry partner involvement, along with a project rubric, design and organizational aids, could significantly increase the rigor and relevance of projects.

The problem of practice is that currently, many pathway projects are still disconnected to the demands of the industry or do not require students to engage in critical thinking and problem-solving skills at a rigorous level. Some pathways continue to do the same projects year after year, in spite of new developments and innovations in the field that beg for project updates. This is especially true of IT, engineering, health, and media, but is also true of law due to legislative changes, and emerging policy issues in this "age of acceleration," an expression used by Tom Friedman in his book, *Thank you for Being Late: An Optimist's Guide to Thriving in the Age of Accelerations.* Friedman states that the rapid acceleration of technological innovation often gets ahead of any societal debate or consideration of the implications. Teachers in pathways could play a vital role in bringing these issues to the surface to prepare our next generation, as industry partner involvement can play a role in keeping teachers updated. The absence of rigor and current relevance is clear through student presentations of projects at their "senior defense." The senior defense is an exercise in which most of the pathway students now participate in, an effort supported by the Pathways Coordinator over the last four years and promoted and developed through monthly pathway leads "Community of Practice" meetings. In a senior defense, students demonstrate how they have met the outcomes of the pathway through key project(s). Increasingly students are required to present their portfolio as part of this exercise. Industry partners and the College & Career Coordinators serve as panelists to assess the evidence of a student's learning. Over the last two years, various industry panelists have expressed their difficulty in coming in at the end to give a "judgement" instead of as a partner in the design of a

project, or with a role in formative assessment, prior to the culminating senior defense. While industry involvement at the summative stage has resulted in a higher degree of commitment and professionalism on the part of students and teachers alike, that effort alone has not been enough to address the quality or focus of the projects themselves. Partners have expressed privately to the Coordinator that the project should have been designed differently or with more emphasis placed on different aspects in the rubric. For example, one partner asked why students didn't explain the user interface aspects of web design, rather than just the artistic qualities. In another instance, students explained patterns found in nature or manufacturing, without relating the pattern to function and ultimately to their field of health, still others in the same pathway described going over to an elementary school to play games with students so that they would "be healthier." This biomedical pathway had students design prosthesis using popsicle sticks, rather than utilizing the District's fabrication lab, mainly due to lack of an industry partner that could provide expertise. On the reverse side, there were also projects in engineering and law, where partners had had more of a formative role, and the level of rigor and relevance was significantly higher.

It is clear from this research that career pathway projects are best developed in concert with a career partner rather than in a vacuum. Input from professionals in the field, through intentional collaborative work between the teacher and the industry partner has resulted in some impressive student projects. For example, an IT pathway worked to help solve real needs of the Bay Area Transit Authority through co-development of an outreach program for hiring, for determination of route expansion needs, and for an improved user experience on their website. An engineering pathway, in collaboration with city planning/engineering staff and help from

their advisory board, mapped all of the abandoned properties in the area and came up with designs for the spaces to improve their community and a homeless problem, using state of the art CAD software and data software. Scaling these types of high-quality projects will require increased partner involvement and perhaps some key tools for educators and partners to facilitate effective collaboration.

Although projects with partner involvement were better on average in terms of rigor and relevance, it was also clear that partners often felt frustrated in the process in terms of teacher communication and follow through. Teachers also sometimes expressed frustration and pressure about differences in learning goals with the partner and reconciling the project length with competing needs, as they saw them.

In order to explore this further, I gave a survey to the pathway lead teachers. All eleven respondents indicated that they thought it worthwhile to work with industry partners on student projects, especially as "a source of ideas," "to co-teach," and "to review." A few selected, "to co-design a project," and one wrote in "to serve as authentic clients" (to solve a real problem they have.) There were various levels of industry partner collaboration cited, from zero to collaboration throughout a project, but all but one said they could benefit from some help to find the right type of industry partner to collaborate with on a particular project.

Educators understand that projects and curriculum in general are best designed with the learning goals as the driver, often referred to as "backwards planning." The question was posed to pathway teachers as to how many had collaborated with industry professionals when establishing the overarching pathway learning goals for students. Over half said they did not do

so, and some admitted they needed to revisit their goals as a team. The same teachers said they did not feel they were up-to-date on industry developments and could use more interaction and PD in this area. When asked if they felt they knew how to effectively collaborate with an industry partner, all said "Somewhat/Depends." While rigor was intentionally not directly mentioned in the survey, it will be considered at the appropriate time when designing an intervention.

After the initial survey, some teachers were contacted by an industry partner to co-design and implement a project. My colleague, the College & Career employer engagement Coordinator expressed interest in my research/action project to help teachers become better at collaborating with business partners, and because she knew of the partner outreach, she encouraged the partner to also loop me into the planning meeting with teachers. This gave me an opportunity to observe the difficulties that arose during or after these project planning collaborations around issues of clear communication and commitment that resulted in some frustrations on the part of the partner. For example, one teacher abruptly pulled out of a project after the partner had participated in a 90-minute planning session and had made accommodations for a much larger group of students than planned to work with groups of scientists at their lab. Furthermore, she communicated to the partner that she had asked the students, and they were more interested in other ideas, which was another error in judgement. At another teacher/partner meeting I helped to facilitate, the teacher would have missed making connections to her curriculum without my assistance. A third teacher wanted to change a date at the last minute. These difficulties expose various issues that need to be addressed with teachers in terms of being a thoughtful and considerate partner, along with other considerations regarding the projects themselves.

Importantly, the problem of practice of students engaging in rigorous, collaborative projects also aligns to the larger district goals and to school site goals. Initial research supports the idea that this problem of practice correlates to CTE goals and to the goals of the District to significantly move student learning by having students engage in relevant and rigorous projects.

Literature Review

Introduction

My district is one of many nationwide focused on career technical education and industry partnerships as the reform strategy for improving college and career outcomes for students. We currently have college & career pathways in our high schools focused on sectors in health, information/communication technologies, engineering, law, media, and performing arts production. Business or industry partnerships were a key aspect when "California Partnership Academies" were formed, and are also a mandatory aspect of Perkins grant-supported pathways. We have been recruiting industry partners in all of the sectors mentioned, and we are continuously rounding out our advisory boards, class speakers, study trip, and internship providers. We are fortunate to have partners now that would like to deepen their partnership through working with teachers to co-design student projects and by playing a role in helping teachers and students with projects in stages, and not just to give summative feedback. This presents a great opportunity that should be met enthusiastically and strategically. If career technical education is to succeed as a reform movement, it follows that the projects that students engage in must engender a high degree of rigorous learning and be relevant to a rapidly changing labor market. Engaging with business partners could be a meaningful step in this direction, provided teachers are willing and able to work with business partners effectively in order to improve the status quo.

In this literature review, I will explore demonstrated benefits of such project collaboration between educators and business in meeting the goals of rigor and relevance is the first topic of this review of research.

Next, the literature on Project-Based Learning, ("PBL") is explored to find models of rigorous projects that include outside partners. We shall consider the defining characteristics of high quality PBL, and identify qualities that are naturally built in when teachers and business partners collaborate on the design and implementation of PBL, such as authenticity. (For purpose of this study, references to "business partnerships" should be interpreted to include industry sector partnerships in areas such as health, as well as research labs, community-based organizations, and governmental entities who are employers.) We will look at findings and resources from three respected, research-based organizations, including the Buck Institute for Education, Edutopia, and Center for Cities in Schools. We will also examine the literature that exposes the pitfalls of PBL and how to avoid them.

Although the term Professional Learning Community ("PLC") usually refers to teachers learning through a process of collaborating with other teachers, there are nevertheless insights that we may derive in considering professional educators and professional business partners as a PLC focused on collaborative learning. Then, since the goal is to find better ways for teachers to collaborate with business partners on projects, it may behoove us to also consider what businesses say about project collaboration between employees: the pitfalls *they* commonly experience, as well as the strategies they utilize. This could be instructive in designing a project

protocol or strategy that incorporates a common vocabulary and understanding of workplace culture.

Finally, we shall review the research about successful strategies to address challenges that have arisen in educator and business project collaboration. This is an area of research that is in a relatively young stage, and one that I hope to further develop through this action research work.

In anticipation of moving into the intervention phase, once tools are chosen and developed based on ideas that surface most compellingly throughout the literature, it is the intent of the researcher/coach that such tools be delivered to teachers through a series of coaching sessions. Therefore, I will also explore the literature on effective coaching practices.

Benefits of Education/Business Collaboration

As our College & Career Department continues to build deeper partnerships with industry, many industry partners have expressed a desire to be able to help to influence the types of student projects and learning goals that are needed in their field. April Treece, Director STEM Workforce Initiative for the Contra Costa Economic Partnership, has brought our College & Career Department a clear message from the companies that employ her as a liaison. “Business partners would love to be asked by educators what it is that they feel students need to learn in order to be prepared for the workforce. Many of them feel that to date educators have mostly put themselves in the driver seat, and are asking employers to partner with them, but in a passive

role, either as a supplier of resources, or in the role of audience for project presentations. They are often bewildered by a project's focus or by struggling to understand academic rubrics."(Treece, 2017 meeting.) Many large companies and organizations, such as Chevron, Lawrence Laboratories, SunPower, Youth Radio, and KQED employ education outreach personnel in order to play a more interactive role with educators, and several such organizations have contacted our district in this regard. So there is a desire and a belief in the value of this type of partnership on the part of business partners, and it is a good time to help teachers to work with these partners more effectively.

"Learning through industry collaboration is critical in decreasing the gap between the real world and the academic environment," say Sara B. Marcketti and Elena Karpova, teachers at Iowa State University, in their study entitled "Getting Ready for the Real World: Student Perspectives on Bringing Industry Collaboration into the Classroom." (Markett, Karpova, 2014.)

Their study explored students' perceptions of the benefits and challenges of working with industry projects as part of a creative thinking and problem solving course. In the particular project under study, two faculty members in the apparel program collaborated with Payless ShoeSource to develop projects that allowed students to apply creative thinking strategies to solve real-world problems. One hundred and ten students from the apparel, events planning, and hospitality majors had a month to work in groups on a defined problem. Students were asked to keep a journal in which they recorded and reflected upon their experiences related to completing and presenting projects developed in collaboration with industry partners. The two representatives from Payless who co-developed the project with the professors were from the merchandising and sourcing department, and together they created the project descriptions. The

projects involved redesigning packaging for various merchandise, and required "(a) researching the industry's typical and best practices related to the presented problem and writing a report (b) developing an innovative solution to address the problem, (c) producing a packaging prototype, (d) addressing costing, transportation and display issues and presenting to company representatives. The benefits reported by students were that they "took the assignment more seriously, invested greater effort, and were more motivated to deliver quality outcomes" due to the authenticity of the work. Students also cited the pressure to impress the company and wanted them to believe that Iowa State students were capable and could come up with good ideas. In particular, students appreciated the opportunity to interact with professionals throughout the project and to get immediate feedback. They cited the project as important to their careers. "Knowing that the Payless team would be in the room took the project to another level for me," said one student. Although this project involved college students, the same student perceptions are found in high schools that engage in projects with outside partners. (Markett, Karpova, 2014.)

One such deep, and multi-year partnership that serves as an exemplar in high schools is called Project Lead the Way. (www.pltw.org.) Many companies that employ engineers found value in co-designed curriculum projects and skills development through Project Lead the Way, and in turn, engineering programs at colleges have been impressed enough to offer priority placement in their engineering programs to students who have had this training in high school. In this program educators and engineers collaborated to write project curriculum. Project Lead the Way ("PLTW") is a nationwide program that has formed partnerships among public schools, institutions of higher education, and industry to increase the quantity and quality of students

graduating from engineering and engineering technology institutions. PLTW developed a four-year sequence of courses that introduces students to the rigor and discipline of engineering and engineering technology, prior to entering college. "Introduction at the high school level attracts more students to engineering and allows students to determine whether this is the career field they desire." The program was developed in the 1980's by a teacher supported by a technology advisory board. PLTW continuously employs educators and industry partners to develop curriculum and projects, and offers ongoing teacher training and conferences for professional development. Many businesses support their local school district programs with monetary resources for teacher training and equipment, because they find the PLTW projects to be an excellent avenue for developing the types of technical and critical thinking skills needed by their companies. Toyota is the latest partner to be recognized by Project Lead the Way, as a "transformative" partner, along with Autodesk, Chevron, The Kern Family Foundation, Lockheed Martin, and Verizon. Project Lead the Way programs are now in 10,500 elementary, middle, and high schools in all 50 states and the District of Columbia. (Corporate News, 2017.) Notable contributions nationwide have also come from Intel, NASA, Bayer. (Engineering and Technology, 2015.)

In our school district, Chevron and Sun Power offer financial support of PLTW. PLTW thus does much of the "heavy lifting" with project and curriculum development, and businesses help with funding, but local business *partner participation* is still a key ingredient needed to give projects a local context and to provide students with real-time feedback, as PBL veterans at the Buck Institute and Edutopia attest. BIE cites "authenticity" as a key element (BIE, "Gold Standard PBL," 2015) and in an Edutopia article, Frank McKay lists the number one pitfall of

Project-Based Learning as "Lack of Real World Connection." (McKay, 2017.) The Center for Cities in Schools, an organization founded by the University of California, developed a "Y-Plan" model of education/business partner project collaboration, and they include "authentic client" and "going public" as key elements in their respected project "roadmap." (Y-PlanBerkeley.edu) PLTW projects are ahead of the curve in terms of project rigor, but without direct industry participation, projects lack urgency and authenticity in the minds of students, and teachers are not necessarily held to account either, without an authentic audience for their projects.

Across the nation, businesses and governments are facing the challenge of high levels of youth unemployment and a shortage of job seekers with critical skills Tkacyk, the National Director of Counselor and Academic Relationships at Universal Technical Institute, sites a McKinsey & Company study (2013) that finds that "…Education providers and employers must actively step into one another's worlds." Universal Technical Institute embraces this model through partnerships with manufacturers of more than 30 leading brands: Ford, GM, Mercedes-Benz, Toyota, and Peterbilt, to create "some of the most innovative and sophisticated education programs in the automotive, motorcycle, marine and motorsports industries. Educators closely collaborate with manufacturers on curriculum and design of labs, and refine their instruction and projects through biannual advisories to align learning with current industry demands. (Tkacyk, 2016.)

Articles such as "A Student Project with a Million Dollar Price Tag" laud the accomplishments of students through teacher/business project collaboration. In this example, students built an entire house in McLean, Virginia that went on the market for $1,325,000. More than 60 students build the house over a 2-year period as part of a partnership between Fairfax

County Public Schools and the Foundation for Applied Technical Education, Inc. Similar projects are completed each year by career technical students around the county. “Small groups of students are provided with instruction from the professional trades in masonry, concrete finishing, painting, plumbing, and electrical work, and heating and air conditioning.” Fairfax County Public Schools and the Foundation have been working together for 30 years, and this is the 16th house constructed through their partnership. Contrary to a prevailing perception, McFarland says that 80 percent of these students go on to college. “Moreover, some of them are now looking at construction management as a possible career.” ” (Techniques, 2003)

Educator/Business partnerships are in fact growing around the world, including in the developing world, and business has found innovative ways to bring the workplace to the classroom, such as physical simulations, setting up a faux hotel in India, or creating a realistic coal mine in Australia. This can also be done through computer/digital simulations, which immerse users in a virtual world to enable the application of knowledge and skills, from marine navigation to business-process optimization. (Barton, Farrell, Mourshed, 2013.) There has been a huge growth in the field of so-called “serious games” designed by industry to train employees and students. This is especially true in the health industry. (Graafland, Schraagen, 2012.) Still, educators find that when students attach a real life industry partner to the project, someone who will give feedback and assess the results, such interactions heighten the benefits and produce better outcomes. Educators also admit to feeling an increased sense of responsibility and accountability when they are working with a real human being in the work world community. Such as a partner can help a teacher customize a project and help with needed areas of teacher growth in order to better support students. (Marcketti, Karpova, 2014.)

The Case for Project-Based Learning as a Model

While some employer partners may bring a high level of expertise in their field, not all such business partners are equally equipped to design student projects. Therefore, such partnerships may be strengthened when a teacher is equipped with a basic knowledge of project- or problem-based learning so that she/he may employ and share such strategies and tools to assess the project under consideration and address possible gaps with a business partner. Project-Based Learning is defined by the Buck Institute for Education as "a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging and complex question, problem, or challenge." (https://www.bie.org/about/what_pbl) Similarly, Edutopia defines PBL as "a dynamic classroom approach in which students actively explore real-world problems and challenges and acquire a deeper knowledge. (https://www.edutopia.org/project-based-learning)

According to Vanessa Vega, Edutopia's former Senior Manager of Research, numerous case studies have proven that when implemented well, project-based learning (PBL) can increase retention of content and improve students' attitudes towards learning. (Vega, 2013.)

"Today's students will enter a job market that values skills and abilities far different from the traditional workplace talents that so ably served their parents and grandparents. They must be able to crisply collect, synthesize, and analyze information, then conduct targeted research and work with others to employ that newfound knowledge. In essence, students must learn how to learn, while responding to endlessly changing technologies and social, economic, and global conditions." (Barron, Darling-Hammond, 2008)

Barron and Darling-Hammond go on to detail research on project learning that found that student gains in factual learning are equivalent or superior to those of students in more traditional forms of classroom instruction. The learning went one step further, by enabling students to transfer their learning to new kinds of situations, illustrated in three studies that they explain:

- In a 1998 study by H.G. Shepherd, fourth and fifth graders completed a nine-week project to define and find solutions related to housing shortages in several countries. In comparison to the control group, the project-learning students scored significantly higher on a critical-thinking test and demonstrated increased confidence in their learning. (Shepherd, H.G., 1998)
- A longitudinal comparative study by Jo Boaler and colleagues in England in 1997 and 1998 followed students over three years in two schools similar in student achievement and income levels. The traditional school featured teacher-directed whole-class instruction organized around texts, workbooks, and frequent tests in tracked classrooms. Instruction in the other school used open-ended projects in heterogeneous classrooms. The study found that although students had comparable learning gains on basic mathematics procedures, significantly more project-learning students passed the National Exam in year three than those in the traditional school. Although students in the traditional school "thought that mathematical success rested on being able to remember and use rules," according to the study, the project-learning students developed more flexible and useful mathematical knowledge. (Boaler, J., 1997)
- A third study, in 2000, on the impact of multimedia projects on student learning, showed similar gains. Students in the Challenge 2000 Multimedia Project, in California's Silicon

> Valley, developed a brochure informing school officials about problems homeless students face. The students in the multimedia program earned higher scores than a comparison group on content mastery, sensitivity to audience, and coherent design. They performed equally well on standardized test scores of basic skills. Other short-term, comparative studies demonstrated benefits from project-based learning, such as increases in the ability to define problems, reason with clear arguments, and plan projects. Additional research has documented improvements in motivation, attitude toward learning, and work habits. Students who struggle in traditional instructional settings have often excelled when working on a project, which better matches their learning style or preference for collaboration. (Barron, Darling-Hammond, 2008.)

Criteria for success on PBL tasks need to be clearly defined at the start of the project, and should include multiple opportunities for feedback, reflection, and time for students to revise their work (Barron, Darling-Hammond, 2008). When this feedback comes from industry professionals or community partners, the feedback is all the more powerful and has increased "authenticity" in the eyes of students.

"[B}y emphasizing the process, effort, and strategies involved in accomplishing a task -- as opposed to focusing solely on the final product -- students come to understand that learning is the result of cumulative effort. This, in turn, improves their resilience and academic achievement." (Dweck, 2000).

Researchers also recommend end goals that reflect professional practice, such as public exhibitions, portfolios, and presentations, which signal the social value and relevance of student

work (Barron & Darling-Hammond, 2008.) When projects are presented in this way to and assessed in by business partners, the partners bring their workplace expertise and industry focus to bear and are able to give students valuable feedback, thereby adding authenticity and career relevancy to the project.

For purposes of this action research project, time constraints do not make it feasible that all teachers who volunteer to work with an industry partner on a pathway project receive intensive PBL prior to the commencement of the project collaboration. However, if PBL research is distilled into its main components, PBL may serve as a valuable model to support the rigor and relevance of the project co-design work and provide a structure for the project that is helpful to teachers and business partners. Post-project interviews of teachers will seek to learn whether more formal training in PBL is desired by the teacher and seen as a way to better support them in their project work with partners. On the other hand, we may find that the professional industry partner is an excellent resource for the teacher in terms of support, facilitating inquiry, and as a reflective partner, and that the key components of PBL were incorporated effectively.

According to the Buck Institute project rubric, essential project design elements are as follows, and these may also serve as a baseline for education/business partner PBL work:

"Key Knowledge, Understanding & Success Skills

The project is focused on teaching students specific and important knowledge, understanding, and skills derived from standards and central to academic subject areas. Important success skills are explicitly targeted to be taught and assessed, such as critical thinking/problem solving, collaboration, and self-management.

Challenging Problem or Question

The project is focused on a central problem or question, at the appropriate level of challenge.

The central problem or question is framed by a driving question for the project, which is: open-ended; it will allow students to develop more than one reasonable answer. It is understandable and inspiring to students and aligned with learning goals; to answer it, students will need to gain the intended knowledge, understanding, and skills.

Sustained Inquiry

Inquiry is sustained over time and academically rigorous (students pose questions, gather & interpret data, develop and evaluate solutions or build evidence for answers, and ask further questions). Inquiry is driven by student-generated questions throughout the project.

Authenticity

The project has an authentic context, involves real-world tasks, tools, and quality standards, makes a real impact on the world, and/or speaks to students' personal concerns, interests, or identities.

Student Voice & Choice

Students have opportunities to express voice and choice on important matters (questions asked, texts and resources used, people to work with, products to be created, use of time, organization of tasks). Students have opportunities to take significant responsibility and work as independently from the teacher as is appropriate, with guidance.

Reflection

Students and teachers engage in thoughtful, comprehensive reflection both during the project and after its culmination, about what and how students learn and the project's design and management.

Critique & Revision

Students are provided with regular, structured opportunities to give and receive feedback about the quality of their products and work-in-progress from peers, teachers, and if appropriate from others beyond the classroom. Students use feedback about their work to revise and improve it.

Public Product

Student work is made public by presenting or offering it to people beyond the classroom. Students are asked to publicly explain the reasoning behind choices they made, their inquiry process, how they worked, what they learned, etc." (BIE, 2015)

Similarly, KQED, in their "Mindshift" educational support materials adapted from the work of Peter Skillmen and Brenda Sherry, identify seven features of high quality PBL

projects, including student generated questioning, student self-control, interdependence and collaboration, complex content, authentic audience, and iterative feedback. (Skillman, Sherry, 2015)

The George Lucas-founded Edutopia, The Buck Institute for Education, and KQED's Mindshift, all respected, research based organizations, have come to similar conclusions about the components for assessment of high quality PBL projects.

While businesses working as project partners with educators does not guarantee that a project will hit all the high notes, it does guarantee that a project will have an authentic problem, client and/or audience and that there will be feedback from an outside entity. The project is much more likely to be complex and generate student questioning, as well as to generate a public product, such as a presentation to industry professionals. These rubric components will be used to assess co-designed and co-implemented projects to see if the results bear this out.

Avoiding PBL Pitfalls

According to Hung (2008), PBL is ineffective when:

- The skills needed for solving a problem are either above or below the learner's abilities, and/or
- The problem asks students to study content that is outside of the content objectives, but required for solving the problem.

It will be important for these pitfalls to be addressed in the creation of project guides and coaching. Frank McKay (2017) identifies these pitfalls (among others):

- Focusing on products over process
- Not planning learning around targeted standards and skills

As will be discussed later in this literature review, the 'process versus product' perspective has been an area where educators and business partners sometimes differ, and therefore the importance of process may need to be discussed during the project design process, so that they can come to shared understanding that takes both process and product into consideration. Regarding the second point about planning around targeted standards and learning goals, the coaches' role will need to help the teacher understand that a project should cover Common Core subject matter standards and CTE standards, if those drive the course curriculum. Projects that do not incorporate these will likely be viewed as extra rather than intrinsic, and in turn, lead to teacher impatience or frustration with a project. This does not mean that the business partners' goals cannot also be a part of the overall design. Both need to be included.

Collaboration in Professional Learning Communities ("PLCs")

Researchers have found a number of practices of PLCs help explain how PLCs can lead to improved student learning by enhancing teacher learning (Andrews & Lewis, 2007; Bolam McMahon, Stoll, Thomas, & Wallace, 2005). The most important aspects of PLCs are: a shared vision and values, a strong collaborative culture, use of data, especially student work, to analyze strengths and gaps, engagement in joint work such as development of common lessons and

assessments, and a concerted focus on student learning and results (Chrispeels, Andrews, & Gonzalez, 2007; DuFour, DuFour, & Eaker, 2008; Hord, 2008). As a researcher/coach in helping teachers and business partners to collaborate effectively on student projects, these critical practices will need to be incorporated into the project planning tool and in post-project reflection. Especially as teachers and business partners seek to create projects that can be replicated for several years, analysis of process and outcomes become important components to inform year-to-year improvements. To do this, each side must be willing to devote some time and thought – and honesty -- to the reflective process in a way that avoids blame and focuses on constructive improvement.

Patrick Lencioni, in his book, *Five Dysfunctions of a Team*, identifies a pyramid of dysfunctions to beware of. At the base, is absence of trust, which leads to a stance of invulnerability: people will be reluctant to admit what they don't know if there is no trust. Therefore, it is important for the teacher and the business partner to get to know each other and establish a friendly partnership at the outset. Next is fear of conflict, which can end up creating an artificial harmony. In coaching teachers and going over project planning tools, it will be important to encourage the teacher to raise concerns or doubts that may arise, and to ask the partner to do the same. Otherwise, a false harmony general leads to a lack of commitment to the project, and snowballs into avoidance of accountability, and inattention to results. (Lencioni, p. 174) In coaching and facilitating collaboration between teachers and business partners, it will be crucial to build a sense of trust by setting a tone of friendliness and a desire to learn throughout the collaboration, and also by identifying shared goals. It will also be important to encourage frank dialog when one side appears to exhibit hesitancy or reluctance, so that once agreements

are entered into, both sides feel satisfied and committed, and will be more accountable to the next steps identified. During the project design phase, partners should identify the results sought and how they will be measured, as well as leaving room to acknowledge that some results may be unanticipated but valuable nevertheless, as the project unfolds and students bring their own unique energy and perspective to projects. A project tool that helps each side to understand its role and commitments, and a timeline and projector calendar, can help parties to honor their commitments and keep the project on track to achieve the desired outcomes.

What the Business World has learned about project collaboration in the workplace

A brief look at how businesses discuss and write about collaborative work within their workplaces may serve as a communication bridge for educators. Whether it be students or workers, what educators and business managers have learned about effective project collaboration have important similarities.

According to the American Express Open Forum writer, Andrew Field, (Field, 2016) six ways that businesses can foster collaboration in the workplace are:

1. Communicate company expectations.

Make it clear that collaboration is the minimum standard. Define roles and responsibilities within the team. Every team member should understand their position and what is required of them. In a collaborative environment every team member takes responsibility for good outcomes.

2. Set team goals.

Ensure concise, measurable goals are set on a quarterly basis. Getting the team to focus on goals will keep individual efforts aligned with desired outcomes. Be willing to re-evaluate goals as needed. All our quarterly goals are published on our PrintingForLess.com intranet. Each quarter the outcome of each goal is also published. This keeps us focused and transparent.

3. Foster a creative atmosphere.

Allow team members to question and brainstorm in a non-judgmental framework. Encourage the team to look at obstacles as being conquerable. Nurture a "can do" company attitude. Ask why, or why not, on a regular basis. One way we cultivate a creative atmosphere at my company is by providing leadership training that encourages character development. We purposefully hire employees who aspire to be and produce their very best.

4. Build cohesion.

Include every person on the team in as many large decisions as possible. Create a means of communicating current work flows to avoid duplication of effort. Initiate daily team huddles where each member shares what they will be accomplishing that day. This keeps everyone on the same playbook and enables team members to re-direct their efforts as needed.

5. Know one another.

Different personality dynamics, skill sets and experiences are present in every team. It is worth the effort to have each member complete a simple personality profile. Share the results and openly discuss likes and dislikes with regard to communication, tasks and personal

focus. At my company we utilize Insight Discovery™ to provide personality and work style assessment. We print the resulting insight "color graph" on each team member's nameplate.

6. Leverage team member strengths.

Position each team member for success by assigning tasks that play to their respective strengths. Reward both individual and team accomplishments regularly.

Establishing a collaboration policy is just the beginning. Collaboration must be consistent and purposeful, with resources dedicated to its success. You may have many superheroes in your office already; but you can build your productivity exponentially by getting them to work as a collaborative team. (Field, 2016)

Deb Lavoy, writing for CMS Wire, advises businesses on pitfalls to avoid in project collaboration. (Lavoy, 2015) Two ideas in particular, are relevant to teacher/business collaboration. She states that "collaboration is only meaningfully possible in an environment where it is entirely comfortable to be human and flawed. The assumption in such an environment is that you are there because you are competent, and that if you haven't nailed the issue at step one, there's a very good reason for it — e.g., it's hard, novel or simply requires multiple inputs to reach its full potential." She also emphasizes that "Collaboration needs leadership …someone looking to create opportunities, engage people around the mission and remove barriers. Leadership is one or more people who set a great example for asking questions, treating people with respect and keeping the focus on what matters." A business partner and teacher need to both see themselves as leaders in this sense of the word.

Jim Stewart cites his top ten reasons why projects fail, and to the list above, his number one is "scope creep." (Stewart 2015) In education/business partnerships, we would not want to dismiss "teachable moments" that arise out of the work, or shut down exciting or interesting ideas that arise out of the project work, but nevertheless one must be aware of this potential pitfall in terms of a project timeline and capacity of the stakeholders. Any "scope creep" needs to be identified and planned for, or perhaps given to a student or student team for extra credit.

It may be helpful to have teachers read one of these articles as part of the coaching process, to get them to begin to consider the perspective and experience of employers regarding collaborative projects. It might be interesting to have a business partner come in to talk to students about how their company approaches teamwork as part of a collaborative project kickoff. A student or students may also be selected to explain to the partner what they know about PBL.

Strategies for Success Learned in the Field

The Conference Board of Canada has published an Education-Business Partnership Tool Kit, developed by educators and business partners together, and they begin with a tool for ethical education-business partnerships.
(http://www.conferenceboard.ca/topics/education/archived/ebp.aspx)

They advise to strive for ideals that mutually benefit all partners, share knowledge, ideas, and perspectives, align objectives, recognize and respect each partner's expertise and contributions, and respect differences among partners. They also discuss adherence to

obligations, and the need to be open and honest when problems occur and avoid making excuses or rationalizations, as well as finding common ground when challenges arise by returning to shared objectives and values. And, finally, "Celebrate and build on positive outcomes and progress made." (http://www.conferenceboard.ca/topics/education/archived/ebp.aspx)

In a study done in The Netherlands entitled "Unravelling the social dynamics of an industry-school partnership: social capital as perspective for co-creation," (Ehlen, van der Klink, 2015) the authors' findings indicated that the social capital theory helped to explain crucial factors of processes and outcomes. "The social capital theory addresses many elements that play a role in innovations, and "a framework for understanding the complex process of co-creation. The authors state that "Sustaining this social capital proved crucial, while managing according to a planned change strategy appeared to be counterproductive." Their study of education/business partnerships was prompted by an era of rapid globalization and high societal demands requiring innovation, creativity, and invention. This study considers a much broader and long term post-secondary and business partnership than the types envisioned between our high school college & career pathways and their business partners, although some of their findings are still relevant. In the scope of the Netherlands study, the project involved educators and business working together to develop a "Leisure Academy" project to achieve three targets: a career development center, improved methods for work-based learning, and an assessment center. They state that these targets were not reached in full, that 16 education-organizational products and services were realized, based on the three targets. Further they found that incidental outcomes were achieved, as validated by the participants. Educators, on the whole, were more positive about the value of these incidental outcomes than were the participating companies. The

steering committee and project management team considered the overall project results initially as not innovative enough, but changed their views on the gains, confronted with the positive findings during the final conference. This is important in emphasizing the need for something such as a final conference where evidence is presented, both quantitative and qualitative, and unintended benefits of the partnership may be recognized and leveraged.

Another study that also takes on the issue of how perspectives and objectives of business may differ from those of educators, is one entitled "Democratic Communities and Business/Education Partnerships in Secondary Education," by Kathleen Knight Abowitz. (Abowitz, 2000.) She cites "mutual suspicions that may be inherent in these collaborations," such as educator mistrust of corporate motives (are they attempting to shape students as consumers or to train their future workforce on public monies), and a fear of them narrowing the educational agenda. On the other hand, "Corporate executives often report frustration at what they see as the agonizingly slow pace of educational decision making." Abowitz concludes that the partnership must be an equal one, where both sides achieve what they need out of the partnership, and guards against a powerful corporation exerting too much influence through financial contributions or politics. Through her study of a particular partnership called "T-Cap" at Taft High School, however, she finds much to recommend the business/education partnership. After seven years of partnership work between committed individuals who had built up trust around shared values, feedback from teacher participants was enthusiastic, and student outcomes much improved. (Abowitz, 2000.)

The Council for Corporate & School Partnerships stated mission is "to identify, create, recognize and support exemplary business and school relationships that improve student

experiences in K-12 schools in the United States. Toward that end, they have developed the "Guiding Principles for Business and School Partnerships." (www.nhscholars.org) The guide was developed with school district administrators and teacher input. It echoes much of what has already been discussed: the importance of developing relationships, establishing common ground around values, goals, and expected outcomes, having a communication plan, and finding ways to public acknowledge the partnership and achievements.

Coaching

Academic coaching will be needed as a way to provide individualized professional development to teachers so that they have a better understanding of PBL and to go over how to use particular project organization tools developed by the Buck Institute, Edutopia, and others, to ensure the rigor of projects (for example, by having teachers identify essential questions, the parts of the project that will develop students' critical thinking, the standards that will be covered, and the learning outcomes identified by the teacher and the business partner.) Coaching will also cover principles of working with a business partner as professional learning partners, what some might refer to as "soft skills." Coaching will emphasize the importance of building relationships and trust, for example, through establishing understanding of shared goals and demonstrating reliability. Then some instruction will be needed to help teachers use the tool to organize project work.

"The process of coaching requires both backbone and compassion. The coach must be courageous enough to be gently irreverent with the client to test the client's view of the world.

However, coaching can work only when the coach cares deeply about the client and is able to cast aside his own ego to support the client's efforts." (McNeil, Klink, 2015, Intro to Coaching for Equity) In the context of coaching teachers to help them co-design and implement relevant and rigorous projects with an outside industry partner, this coach/researcher will keep this in mind if faced with a teacher view that places a lack of confidence in students' abilities to learn and rise to a certain level of rigor. It is easy, in a district with students who are faced with many challenges, to operate from a "deficit" point of view, rather than to motivate and support students in learning that engages them.

In developing a coaching stance, the authors warn against the assumption that finding the right tool is the key to catalyze lasting changes in behavior. In the right conditions, they state, a well-designed tool can catalyze immediate change, but lacking purpose, relational trust, or appropriate context" the tool will not be likely to work. (National Equity Project, 2015)

The National Equity Project also identifies six helping interventions or styles, adapted from Heron, J. (2001), and when to use them. They are: Prescribing (giving advice or recommendations), Informing, Confronting (challenging assumptions, stimulating awareness), Cathartic (helping colleague to release tension), Catalytic (helping colleague to self-directed learning, solving their own problems), and Supporting. Helpful sentence starters and questions are given to help the coach with each of these six interventions.

The Reach Institute for Education Leadership, in their handout entitled 420 Instructional Coaching Skills: Coaching Stances, identifies three coaching stances to assist the coach: Instructive, Collaborative, Facilitative, in progressive order.

In conclusion, the research has shown the benefits to educator/business collaboration, agreement among researchers as to the elements of high quality project-based learning, which includes real-world applications to problems, and authenticity. We have been provided with rubrics and warned of the pitfalls. We have also examined the research briefly on professional learning communities and what tends to make them work well. We have looked at project collaboration from a business point of view to learn what they have experienced and learned about project collaboration among their employees. To synthesize these, we have examined articles and studies on successful strategies of educator/business collaboration and tools that have been developed to facilitate collaborative project work. And finally, we have looked at some successful coaching strategies to be used in order to provide individualized professional development of teachers to become more confident, knowledgeable and effective in their work with business partners. All of these studies have been used to create an intervention plan to address the problem of practice: Teachers do not collaborate effectively with industry partners to create relevant and rigorous career pathway projects.

Intervention Plan and Methodology

My theory of action was that if teachers were coached to become more effective in collaboration with industry partners to co-design student projects, and if they were also given some professional development around elements of high-quality project-based learning, their projects would become more relevant and rigorous. The coaching plan I developed to address how teachers could become more effective at partnering with industry was based on many articles described in the literature review in which educators and employers reflected on their collaboration process: the pitfalls and difficulties and the aspects that helped the collaboration to

be successful. For the coaching on high-quality project-based learning, I included a detailed and summary rubric from the Buck Institute, The action research was conducted over a period of 6 months, due to the need for time to line up industry partners with an appropriate pathway teacher, and to conduct the coaching intervention at a time that the teacher was able and willing to plan a project. This also limited the number of teacher participants to five. In 4 out of 5 cases, the industry employee was someone who was designated by the employer as the educational outreach person for a large organization. Admittedly, this limits the findings and further study will need to be done with smaller employers who don't have a designated person for educational outreach. In the one instance in this study where the teacher didn't work directly with an educational outreach person employed directly by the company, an umbrella educational outreach organization for engineering had recruited young engineers from various companies and arranged release time for those engineers (although their workload was not decreased, as they explained to me walking to the parking lot together.) In that case, the three engineers from three companies that were working with the teacher and students were operating under a project design plan created for them by the umbrella organization. In this case, I compared their project organizational tool with the one that I had created, as well as with the essential elements of PBL to ensure that they were in alignment. (This project had to do with having students design bridges in groups to meet certain load, design, and cultural requirements.) I determined that indeed their structure was substantially similar, and therefore it would be acceptable to the research to go with what the engineering organization had created. However, as will be discussed in Findings, the teacher concluded that for next year, she wanted to use our tool as well, because she wanted to remember certain activities that she needed to do and improve on next time.

Before the project and the methodology was fully created, and the action research underway with the each of the five teachers, my work had already begun in a less structured and data driven way, and this was a helpful precursor to my formal work. In those instances, I could see that my facilitation was having a positive effect on the project planning and design. The situation arose because a scientific research lab had come to me with several project ideas on which they wished to partner. At this point, I had already been immersed in the literature review, and thus my facilitation was informed by my findings regarding PBL and pitfalls of education/industry partnerships. In this case, there were two teachers, one in the engineering pathway, and one in the biomedical pathway, to whom I reached out, and acted in the capacity of liaison and facilitator to ensure that they co-constructed projects that met the teacher's learning goals, and were connected and built upon what students had learned or were in the process of learning. I also acted as facilitator to ensure that there was clarity and commitment regarding the timeline and responsibilities, and because this was already upon me, I rushed out the Project Design and Planning Template that would, as a result, be modified and incorporated into the formal action research study. In both cases, the partner and teachers expressed gratitude for the help in constructing a project that met their goals. In one case, I reminded the teacher of a project I knew she was doing with another partner and suggested that this project would be a great springboard, moving students from architectural planning for blighted spaces in the city, to selected of energy-saving building materials that fit the situation. As a result, it was decided that students would arrive with their own CAD architectural drawings, and this would serve as the starting point for work with the scientists. This improved the enthusiasm of the teacher, students, and scientists, and made for a great experience. In this case, as the teacher had done several projects

with partners in the past, she was able to create a more rigorous and integrated project without too much help, but she liked using the template as she said, “This really helps me to keep it all straight, with so much going on. I know exactly who is responsible for what and when. I’m also really excited about knitting all this together, and I feel great about putting the planning time in because I want to do this next year too!” This teacher, in fact, has taken on another industry partner co-design project, and thus became a part of the formal action research study. In another case, the teacher was a chemistry teacher in the health pathway that I did not know well, and she and the partner needed a bit of help in figuring out a good way to link crystallography to the health field, which turned out to be by a study of aspirin put under different conditions. What she said was, “The kids loved visiting the Alternative Light Source lab and meeting all the scientists, and that would have just been a great field trip. But it was a much better learning experience for students to set up an experiment ahead of time and make predictions, and then see what happened and talk about it with the scientists. They felt pretty important! And I felt it was a good use of my instructional time.” These two teacher projects are not included in the data because no baseline data was collected and I did not coach them before the planning design session with the partner, but instead actively participated in the planning session as a facilitator. Subsequently, it was my goal to build greater capacity for teachers to do this on their own with some coaching ahead of time.

The table below details how the more formal intervention for this study was constructed, and the data associated with the various parts.

Component	Activities	Purpose/Sub-Question to be answered	Data to be Collected	Type of Data
Baseline data on teacher's experience in 1) collaborating with business partners on projects, and 2) on PBL.	Survey, Baseline questions discussions	Assess whether teachers feel collaboration with partners is worthwhile, their level of experience, and what they feel their challenges are.	**Survey responses, Baseline Q & A's.**	Impact
PBL article, Essential Elements Checklist, and Partner Collaboration Checklist	Coach provides and Discusses Article "Gold Standard PBL: Essential Project Design Elements," Essential Elements Checklist, and Tips on Collaborating with Business Partners (Checklist) with teacher	What are key design elements for a rigorous and relevant project to do with partners? How can I as a teacher become a better project partner in a way that also	**Notes from Coaching session:** What is the level of teacher understanding of the ideas discussed in articles? Where did the teacher rate herself on the checklist if applicable, regarding prior projects? Did teacher indicate that the articles were helpful? (To self: Did you discuss this in greater depth after 1st experience in coaching?)	Process & Impact

Project Management Skills Development	Explain Project Planning Tool as a way to record learning goals, agreements, next steps, when they are to be done, and who is responsible. Communicate the need for teacher and partner to establish communication points and process. Ask teacher to make copies for the session with partner.	Does the teacher understand how to manage a project with a partner, and does teacher view the tool as being helpful potentially?	**Notes on process observed during teacher and partner collaboration.** Did teacher and partner use the project planning tool throughout the project? **Interview post-project** to obtain constructive feedback on project organization tool.	Process and Impact

Initial Teacher Planning Session with Partner:	Coach observation notes. Intervene at end if points are missed in planning, following a model of Guided Practice.	Has the coaching helped the teacher to internalize the components of the pre-conference and was she able to co-design effectively?	**Observation Notes/Script of Teacher/Partner Project Planning Session:** Did teacher address all essential elements of PBL, establish clear agreements, timeline, and communication process, as listed in the collaboration tool? Did teacher utilize the design and project management tool?	Process & Impact
Debrief of Teacher/Partner Project Planning session	Coach shares notes with teacher and gets teacher analysis of process and outcomes.	Is more coaching needed? Is another partner session needed, perhaps by phone? If so, is teacher able to identify gaps and address them?	**Notes on debrief.**	Process & Impact

Mid-way Check in	Coach checks in with teacher and partner by phone to see if the timeline and agreements are holding	Is the project on target? Are parties meeting their obligations? Are students able to do the project in the allotted time? Are adjustments needed? How can those be made without drawing the project out too much? What obstacles arose? Does teacher need additional coaching or strategies?	**Project planning tools**: is it updated with actions completed? Did the teacher and partner go another route, if so, gather that information. **Notes from Verbal check-in with teacher and partner**: How are the teacher and partner feeling about the project so far?	Impact

End of Project Conference	Coach administers a post-project survey to teacher and business partner through face-to-face discussions.	Was the resultant project more rigorous and relevant than previous projects the teacher may have done, when not working with an outside partner? Was the quality of student work enhanced through engagement of an outside partner? Was the experience satisfying to the teacher and to the partner? Do they each have suggestions for coaching others?	**Survey teacher again with baseline questions.** **Assessment of project with rubric.** **Assessment of student final presentations**. **Teacher, student, and partner reflections.** Would they do it again? What would they do differently? The same?	Impact

In order to organize and analyze my theory of action that teachers would design more rigorous and relevant projects if they worked effectively with an outside industry partner to co-design a projects, I organized and coded my data, (including surveys, observation notes of interactions

with partners, coaching notes/video, project evaluations on PBL rubric, and interviews with each of the five teachers and their partners) around three research questions:

1) **Did teachers collaborate effectively with the industry partner, based on tips and coaching discussions developed from the lit review?**
2) **Did teachers organize and manage the project effectively in terms of project steps and timeline in a realistic and clear manner, documented for reference by all parties? (And was this affected by whether or not they used the Project Design/Organization template?)**
3) **Were the final projects that were co-designed with an industry partner more rigorous and relevant than baseline projects?**

Analysis & Findings

Question 1: Collaboration: Did teachers collaborate effectively with their industry partners?

A key goal of the intervention was that teachers work more effectively with an industry partner. Generally speaking, teachers did collaborate effectively after coaching. Teachers were given guidelines to keep in mind regarding effective collaboration, and these ideas were fleshed out in my coaching with examples and articles that teachers were given to read, which we selected on the basis of my literature review. I discussed these ideas at greater length with teachers as the need to do so became apparent. Observation notes taken by the coach during the teacher/partner planning sessions served as impact data to measure whether the coaching intervention was effective. The observation notes indicate that teachers followed the guidelines established. They came prepared with related curriculum materials, an idea of the unit or units that they wanted to propose collaboration around, and gave the partner an idea of the level of students skills and previous experiences, which was identified in the article by Hung as a key aspect of successful collaboration. Teachers communicated in a friendly, inquisitive, and clear manner. One obstacle of communication frequently mentioned by partners and in the lit review is the ubiquitous use of "Eduspeak" or acronyms. All of the teachers caught and corrected themselves when they used an acronym, and stopped to explain it.

Although it was a very busy time at the end of the year, and that may have negatively impacted the degree to which teachers responded in a timely manner, industry partners communicated that four out of five teachers met this requirement in their view. However, I did prompt two of the teachers, and there is still room for improvement here. Had the teachers responded earlier, the

projects all would have been fully planned at this writing. As it is, the teachers and the SRI will be continue to work on details on three projects this summer. In the literature view, regular and timely communication with teachers was a major obstacle to mentioned by industry partners. The degree of completion on the agreed-upon timeline constitutes impact data, which two of the teachers did not meet; however, as the partner in this case expressed satisfaction and a desire to continue the work, and even deepen the partnership, the data in this case is mixed.

Four out of five teachers took care in the collaboration to negotiate a project that met their learning goals, while also incorporating learning goals that the partner thought important. This was a key area addressed in the coaching, as it was emphasized in the literature review as a major pitfall of these kinds of project partnerships. However, the negotiations were aided by some coach intercession to ask clarifying and probing questions of both the teacher and the partner that tended to help the collaborative process move forward. Therefore, this area has emerged as key skill to be developed and encouraged in teachers, as is discussed further in Implications.

Unpacking the data on effective collaboration for each teacher is instructive. The first teacher that I coached ("Teacher A") seemed to negotiate the project quite well during the planning phase, but during implementation, he struggled with the time commitment and did not meet the project deliverables or the the desired learning outcome. While this is related to project management, it was also a failure in following through on the collaboration through communication. He had gotten sick and missed a few days of class, and therefore had fallen behind. Instead of communicating this to the partner or reaching out to me for some help, he decided to "wing it" and cut corners, with disastrous results. He also did not reference or add to

the agreements and details on the project design/management template. Interviews with the teacher afterward indicate that it was a combination of him being overwhelmed but also deciding he didn't really need the organization tool. As a result, he and the students arrived at the partner's lab with one soil sample instead of the three needed for comparison, and it seemed that the teacher had spent more time preparing students to exhibit their prior knowledge than to encourage them to bring an inquisitive mind and ask questions. As Lencioni articulated in "Five Dysfunctions of a Team," effectiveness of a team effort is adversely affected if team members do not have enough trust to admit their vulnerabilities and to signal when they need help. It was apparent that the teacher was not as focused on the learning goals as he should have been, but was more concerned with impressing the partner with what his students already knew. The industry partner communicated to me that she and the scientists involved very much liked this project management template and asked if they could use it with their other high school partners. This came about when I had asked a question about how the information presented by scientists and the students in the experiment might help to answer the "driving question" that had been developed by the teacher and the lab's educational outreach person. Her supervisor at the lab stopped me after the session to ask, "Tell me more about this template and driving question. We do these projects with other schools, and that sounds like something I would like to borrow to use with all of them." So I showed her the template, and she said, "Yes, it was sure a shame that the teacher didn't use this! But I want to give this another try, so if you can work with some of your regular pathway teachers, let's arrange more project collaborations next year. This is something I would love to build on!"

As a result of my experience with Teacher A, more checks on progress were made with the other teachers and partners as well. Staying in touch during the project, and communicating when issues arose may have helped him to make preparation corrections and to meet or honor his obligations. Unfortunately, the teacher was unable to honestly reflect on the project, because his defensiveness got in the way, and he simply downgraded his learning goals for the project and the project implementation trip. “The exposure was good anyway.” This experience, with a teacher that I had not previously known, caused me not only to do more check-ins, as previously mentioned, but also to use more persuasion to get the teachers to use the project design template.

The second teacher that I coached (“Teacher B”) is an engineering pathway teacher; a teacher that worked as an electrical engineer for 15 years before becoming a teacher. Even so, co-designing and implementing a project with a partner was a challenge for her. In this case, the EAA, Engineers Alliance for the Arts, had designed a project around bridge design and building and assigned three young engineers whose release time was arranged with their respective employers by EAA. The driving question was established, as were some scaffolded learning activities and a project calendar. The engineers came to the classroom every Friday. The reason I refer to this 10-week project as a “co-design” is because it was necessary for the teacher to design supporting curriculum during the other class days and to work on the skills that she had taught her engineering students and wanted them to practice. Because the EAA had a template for the project, she and the engineer partners did not use the Project Design/Planning template that I had designed, but instead followed the EAA template. The engineers reported to me that the teacher had made sure to communicate well with them through the project, but in reflecting on the collaboration near the project’s end, the teacher herself saw many ways, in retrospect, that

she could have influenced the project by being a more active collaborator. She stated that she wanted to improve upon the collaboration and implementation of the project for next year. What she came to realize is that the project is designed for all students, not just for engineering students, and therefore she should have discussed this in greater detail with the partner so that she and she and the partner could have found ways to increase the level of rigor for her students. I had decided to record my later coaching session with her so that I could listen more intently without having to take notes, as had been the case with Teacher A. This was very helpful. This recorded session occurred about three quarters of the way through the project. The teacher at first said that students had done all the assignments along the way, but then admitted that on the day that the engineers expected to see completed drawings, some students didn't have their drawings ready because they had changed their design a few times. I asked if students used Inventor or another CAD program to create their drawings, or if she had shared with the engineers that students had this type of training, and she said no, that she wished that she had done this, but that she didn't because it had been a while since students had used that program, and she felt she would have needed to review it. When I asked her if she would plan to work this in next year, she decided to do that. She also realized during this session that she had not guided students to research the topics related to design within a particular community culture and geography. Next year, she said, she would strengthen this piece to increase the rigor, and actually have them cost out and study new and existing materials. Importantly, this awareness on the part of Teacher B came about as a result of the coaching discussion and inquiry, and her own reflection and analysis. I encouraged her to have a similar project reflection with the partner before embarking on the project next year. Teacher B's collaboration weakness can be summarized as not

adequately sharing and planning for a project that takes into consideration her students' prior knowledge and skills. As the Hung article advised, the teacher must play an active role in making sure that a project is not below or too far above their students' abilities. This was an area included on the guideline used in coaching, but it presents a good example to use in future professional development. As the teacher explained, "The project parameters were already set, and I guess I thought I shouldn't try to change things, but in fact, I should have talked this through more with the partners. It was also due to the fact that I didn't want to over represent my students' skills, and I was not sure how much they had remembered from the previous year. But now that I've done it once, I would definitely collaborate with the partner and to scale up the rigor."

The next three teacher/partner projects, Teachers C, D, and E, were all teachers who use Project Lead the Way curriculum, but who wanted additional projects that either fill gaps that they have identified, or enrich curriculum areas that they felt were dry and didn't have enough hands-on work to keep students engaged at a high level. They all worked with the same partner, SRI, with whom I had contracted to design projects that would have students utilize our fabrication lab. (The fabrication lab has programmable equipment such as 3-D printers, vinyl cutters, and a large router.) In the cases of Teachers C, D, and E working with SRI, teachers were informed in the initial coaching session that the partner, SRI, had been paid to do the heavy lifting of the project design, and had been given a tour of the fab lab. The starting point for them, then, was to identify the curriculum area they wanted SRI's help with, and for them to engage with the SRI employee to brainstorm and eventually come up with a project request that met their learning goals and those that SRI felt were valuable skills for students to learn real-world skills in conjunction with

the fabrication lab. Collaboration began with SRI began with a video conference, requested by the teacher, once I had e-introduced the partner and teacher. During this project design session, (as coach I listened in) the teacher and partner decided on the parameters of the project. All of the teachers had ideas ready, as I had encouraged them to do in coaching. SRI requested copies of the related curriculum, and the teachers all sent that in a timely manner. SRI then developed a project proposal, communicating with the teacher through email as questions arose. It was crucial that teachers communicated their timeline and summer plans because this was coming together very late in May and June. The plan was then for the teacher, the partner, and I to meet at the fabrication lab to go over the project in detail and make needed changes and additions.

The SRI partner used and shared the Project Design template and shared it as a Google document He and the teachers filled in with more detail during project collaboration at the fab lab. Once the Adjustments were made to the project on the template at that that time, and student handouts were attached. Two out of the four projects are currently fully ready, and the partner and teacher have decided to continue to work on the other two, as they were not able to finish at the time of this writing. Teachers have all agreed to implement the projects during the upcoming school year, identified the month, and have agreed to provide SRI with feedback so that they can scale the project for others if desired.

Looking more closely at each case individually, Teacher C did a good job of co-designing and explaining the parameters of his request, as well as establishing a friendly, collaborative tone. The teacher was able to hold up materials and past projects to show the partner during the Skype video conference, which was very helpful. A good question raised by the partner was “Is this project about building to specs only? Or is it about designing? Assembly?

Both? Instead can I have students respond to design challenge questions?" Teacher C expressed enthusiasm for this idea. In addition to the design challenge vehicle for Teacher C's 9th graders, they also discussed designing fan blades for a turbine engine for use in a hovercraft or fan boat like the ones used in the Everglades as a 10th grade project. It was clear that both the teacher and partner were having fun exploring ideas and trying to come up with the most engaging learning experience that would be doable for the students. The SRI partner shared some examples with the teacher as to how GE and other companies were using similar techniques, not only in their R&D, but in their production of real parts.. The discussion was a very rich one, and it was clear that the teacher and they partner were connecting in a positive way, thus fostering the creative atmosphere identified by Andrew Field in the American Express Open Forum article, as so important to industry-educator partnerships.

In a post-conference debrief with Teacher C, I probed him a bit to clarify a statement he had made to the partner agreeing that perhaps the students could send their 3-D printer requests remotely and someone could pick up their projects. I asked him if he thought this met the goal to have students in the fab lab, engaged in more hands-on work, and he said that no, he realized they really need to make sure students do this work in the lab. The use of the programmable router was also discussed, which students, I pointed out, had never seen. Two weeks later, Teacher C met the SRI partner at the Fab Lab as planned so that SRI could present the project that he worked on according to the initial conference he had with Teacher C. SRI had used the Project Planning tool, along with some other documents that he said he would share in a Google folder, along with the Planning tool. He projected that onto a screen, and he and Teacher C discussed the project using those guidelines. SRI explained that he had taken the previous project

supplied by the teacher, and upgraded it to be more than an exercise in students building to specifications, and made it into a design challenge, as discussed earlier. He and Teacher C talked about the design process as each understood it in their experience, and found much common ground. The fab lab manager was there to help with lab capabilities and suggested using the vinyl cutter for several pieces, and how it could be programmed using CAD also. They discussed whether there would be time for students to build prototypes (3 hour 3-D print) AND the full size (4.5 hours), as it would give students a chance to make sure everything fit together right and also to practice scaling. They also discussed and planned to use the router (a first for students) to build the ramps for the vehicle design testing.

They all discussed how and when students would use the fab lab and also use partners as authentic feedback partners. Teacher C suggested using a feedback site called Nepris to give feedback on the designs before building. SRI would provide the summative feedback. It was clear to the researcher that the collaboration of the partner, teacher, and fab lab manager was creating a great deal of momentum and synergy and a much-improved 9th grade student project.. The project template was filled out and a general calendar plan made to work out logistics.

Teacher C then asked SRI about the 10th grade energy unit project, and here is where the teacher seemed to encounter some discomfort and difficulty in negotiating the project with the partner. SRI suggested the next project would be a motor for the cars. Teacher C was silent. I remembered from the conference call that the two had discussed various energy sources such as hydrogen, wind, solar, and reminded them of their idea about students designing rotor blades for maximum efficiency to move through water, such as a fan boat in the Everglades. Teacher C

looked relieved and said that he wanted to return to the idea of a boat, and so they decided to settle on a vehicle that could travel through 2 inches of water. In debriefing with Teacher C, he expressed that he had felt some letdown initially with the partner's idea, but had gotten a little stuck with how to tactfully express his desire for something else, because he didn't want to be too demanding or to undermine the good feelings they each had about the previous project. This "fear of conflict" as articulated by Lencioni, was something that got in the way temporarily, but was resolved with some help from the coach. Teacher C and the partner are about to meet so that the partner can go over the redesigned 10th grade project. The teacher is also arranging for the partner to come with him to an upcoming professional development. It seemed clear to me that this partnership is strengthening and will continue, and the level of comfort and trust will increase with time.

Teacher D is also an engineering teacher, but at another school and one that teaches upper level students, and her focus course was a 12-grade course called Civil Engineering and Architecture. After coaching, she did a good job of requesting the type of project she envisioned and of setting the parameters of the project with SRI: students would design and build an architectural model, complete with electrical circuitry so that their building would have workable switches. This was a move to enhance a project that she already does in which students build to Habitat for Humanity guidelines, which she shared with the partner. Students in the past used Revit (by AutoDesk) to design their buildings, but they did not that the design to program the 3D printers or laser cutters. Instead, they built by hand. Teacher D knew she wanted to do more, but she hadn't made time to plan that out, and she expressed that she was grateful to have a partner help her to do that. Interestingly, at the second design meeting at the fab lab with the partner, she

got more than she bargained for, which caused her to push her thinking and capabilities. The partner wanted to incorporate student choice and offer several design challenges, one was to create a lighting system, but students could also choose an HVAC system, an alarm system or a flood warning system. Although she remarked more than once that "This is going to be a lot of work; I am going to have to do a lot of review," further probing questions on my part helped the partner to explain to her that these were all not much more complicated than making a light go on and off. As the partner took time to explain and demonstrate how everything could work, Teacher D seemed more open. The partner suggested that she could start with the lighting challenge and add more creativity by encouraging students to vary the shape of the ceilings, such as vaulted ceilings, or emulate track lighting. Then, he said, the other design challenges would be there for her to pick up when she was ready. The fab lab manager was also present and offered to help. This brought up another type of obstacle in co-design, wherein the teacher perceives that the partner is making the project too hard, rather than too easy, as in the case of Teacher B. In this case, however, the teacher was open and flexible enough to take on the project as designed by the partner, with his promise to help again over the winter break. Because she was trustful enough to admit her vulnerabilities "without fear of conflict" (Lencioni, 2008) she was able to leverage the combined strengths of her partner with her own. (Field, In this way, she demonstrated an effective collaboration stance: she was honest about her misgivings, but stayed and talked them through with the partner.

And finally, Teacher E, a biomed teacher, also partnered with SRI. After our initial coaching session, and he talked to the partner to discuss a project based on a prosthesis unit. The teacher and partner discussed the viability of having the health/biomed students work in pairs with

engineering students for this project. I reminded him that the timing and logistics, while not impossible, would be complex and would require careful management and collaboration. It would be important to share the project planning tool with the engineering teacher as well as with the partner so that the all could have some formative input and act as a "reality check" to feasibility, and to devise creative solutions. Teacher E has now shared his current prosthesis lesson plan (using popsicle sticks) with the partner. Teacher E also was forthcoming with the partner to explain that he has zero knowledge of the fab lab, and will need the partner to guide through every step. He showed good collaboration skills in negotiating the project to meet learning goals and in following through with commitments. He provided materials about the previous way he did the project. However, Teacher E was leaving town and then his wife became very ill. Once he did resume communication, he and the partner scheduled another session to test out of the project in the fab lab that will occur after this write up is concluded. In light of the delay, the teacher and partner also arranged to have a second conference call to go over the project details designed by the partner, ahead of the actual project "walk-through." The teacher agreed to talk in more depth with the engineering teacher ahead of that so that he could determine whether it would be viable that the project be a collaboration between health and engineering students. The teacher and partner are now using the project template to design and check in with each other on the project. Partner has stated that his ability to meet with the district fab lab manager and myself during the time he was not hearing from the teacher was of great help in preventing the project to continue. He also came up with a way to do the project without the collaboration of the engineering students, in case that became logistically untenable. In this

case, the data shows that Teacher E did not quite meet the standard of effective collaboration, but he did fairly well on challenging circumstances.

By the time we reached this fourth project with our SRI partner, It was clear to me that he was becoming more adept himself at working with educators and systems. He has encountered a teacher who wanted more from a project, (Teacher C for the 10th grade project), a teacher who needed encouragement and support to step up to the project level, (Teacher D) and a teacher who is going to need a couple of different options (Teacher E: with or without engineering students involved!) Encouragingly, now that all four of his co-designed projects are nearing completion, he has asked if we could participate in more project co-designs of STEM projects under a grant that he would like to apply for together. He has also stated a personal commitment to follow the implementation of the projects and to participate in project reflection and look at the data together. This desire of SRI to continue the partnership with the district and teachers also serves as process data that the model of the intervention has provided a sufficient and workable one from a partner's point of view.

The coaching of the teachers on effective collaboration had a positive impact on the effectiveness of their collaboration in all cases, to a greater and lesser degree. All teachers exhibited the type of openness, flexibility, preparedness, communication, and appreciation of the partner as had been discussed during the coaching sessions. The coaching and debriefing also resulted in teacher reflections toward improvement in particular areas of weakness. This was the case in four out of five cases, with the exception of Teacher A, as has been discussed.

Question 2: Project Organization: Did teachers organize and manage the projects effectively? Did the project template help in this regard? This question is related to the first since the organization and management is closely tied to effective collaboration with a partner, however, I decided to ask this as a separate question because it is even more about process data. It was also a key area of importance cited in the lit review as to why projects with outside partners fail.

As we have seen with Teacher A, he did not follow through, or use the template after the first session, and as a result the project failed in its stated objectives. While he did not say that the template could have helped, his partner did say that, and in fact, asked to use it with other educational partners. In this case, I would also conclude that the process failed due somewhat to the fact that the project was too rushed for a teacher with whom I had no prior relationship, and also because I should have had more frequent check-ins.

Teacher B was an effective project manager from the standpoint of the partner, for the most part. Her students did the assignments required and competed in the regionals with their designs, so she met the deadlines. Throughout the project she used the template from the organization hosting the competition, but she has decided to use our template in the future, and in fact has already used it to make notes for next year's project. She has reflected on many ways that she will improve in her project management and has said that this tool will be more effective for her. "I won't be teaching this same course next year, so I am really glad that I have the project management template to pass along to my colleague. This way I don't have to start at the

beginning, and we have this template to help us when we have our pathway collaboration meetings. We are often managing more than one project at a time, and that can be very challenging, so having some coaching on that process, a partner, and a template to use, was for me, one of the best types of professional development."

Teacher C has been a very effective project manager insofar as the planning of the project goes. His project template is ready for use when he implements the project next year. "I'm glad to know that I'll get a similar project design/management template from [name omitted, refers to Teacher B."]

Teacher D took a back seat to the partner in the project management, but this was an effective way to" leverage team member strengths" as advised in the literat`nd they now have a solid plan. "I like using the project calendar, where we can fill in the activities for "week 1, week 2, etc., and I can then move that to whatever date we end up starting. For me, also, thinking about how to adjust lessons ahead of the project to lead into the project better was also helpful, and I would include that in my management of the project."

Teacher E has been a nominally effective project manager, but continues to collaborate with his partner to work out the project steps and timeline. Again, here the partner's organizational strength in this regard will be an asset. Teacher E concluded "I can see the steps I need to take to manage the project, and that it is going to require mapping out collaboration time between our health academy and the engineering academy. I also now will make reservations with the fab lab ahead of time. I feel like I'm pretty creative and I have plans in my head, but still

things end up being last minute, where I forget to line some things up in advance. So I think this will help."

One additional finding regarding project management was that a coach/coordinator can be very helpful by introducing partners to resources available on a district-wide basis. In this case, to assist SRI in working with Teachers C, D, and E, I arranged for the partner to have a tour of the fab lab with the fab lab manager and myself. In this way, the partner was able to obtain an inventory of equipment, materials, and software that he could include in his project development for any of the teachers. I now have that written inventory that we will update and share with all the teachers and partners in the future who may be interested in using the fab lab. I also asked the partner to communicate with us as his thinking progressed, to let us know if he wanted us to order any additional materials. Letting partners know that we have this ability to obtain needed resources is an aspect that I plan to add to project template or list related to working effectively with partners. While working out the logistics, given the time that it takes 3-D printers to print, may be challenging, I suggested to teachers that they should consider the wealth of resources we have (three fab labs, as well as a 12-passenger van, to transport students in shifts.) I also suggested that working out a timeline and requesting the lab time early in the year would be key. Logistics in these cases is more important that in the first two projects, due to the use of the fab lab, and I encouraged Teacher C as well as Teachers D & E to use the calendar in the Design/Planning template to backwards map the project out early due to the challenge of logistics involved. They have now done this, and the partner, SRI, said that he will participate in giving students feedback and that the calendar will help him line up others at SRI to help with that. In looking at my observation notes, it is clear that the area of project management is an area

that needs to be given greater attention by teachers, because most of them needed reminders to fill out details, responsibilities, and timelines for specific actions. Since there was no baseline for a data comparison in this regard, this data speaks more to whether the process or structure of the intervention seemed to be helpful, which seemed to be the case, based on feedback from the teachers and partners as well as plans laid out on the templates.

Question 3: High Quality PBL Projects: Were the projects more rigorous and relevant after the intervention?

Before the coaching on essential elements of high-quality project-based learning, none of the five teachers participating in the study had had specific training in Project-Based Learning ("PBL), either from the Buck institute or another organization. The biomed pathway teacher stated that he had had training in Design Thinking. All five of the teachers wanted to participate in the study and stated that they believed that working with a partner on a project could help to increase the rigor and relevance of a project and inspire students to strive for greater excellence. As part of the baseline interview teachers were asked to think about a project they had done that they thought was one of their best, and once they had that in mind, they were asked to explain the project and to assess it against the "Essential Project Design Elements Checklist" from the Buck Institute.

This impact data regarding Teacher A reveals that the project as initially designed by the teacher and industry partner met the PBL criteria, and was much more rigorous than his baseline

project -- had he followed through as planned. Unfortunately, as discussed previously, this was not the case, due to issues related to poor communication and project management skills.

Teacher B came to realize, through more reflection on the PBL rubric and the Project Design template, that although her partner project met many of the PBL elements, through more careful scrutiny of the elements of PBL and coaching, she came up with many ways that she wanted to improve upon the rigor for her students next year. For example, the student reflection piece was not part of the EAA project requirement, but is an essential PBL element. Together we examined again the look BIE explanation of student reflection: that students reflect on what and how they are learning, and on the project's design and implementation. Perhaps, I suggested, she could ask students about some of these project improvements that we had discussed. The teacher subsequently did this with her students and now is more confident in her plan to make the changes based on student reflection. The teacher has also decided to go back to the Project Design/Planning template to map out the way she would bolster the project and schedule activities in to heighten the learning experience. For her this was a way to capture the improvements and embellishments that neither she nor her students could get from the EAA site alone. In a final interview regarding the process, Teacher B said that she felt the coaching will help her to improve the rigor of this project next year and also to negotiate projects more actively in the future. She said she wished she had used the project template from the beginning. As a result of this work, she also recommended that her partner engineering teacher, teacher "C" participate in this work with me and another partner. In this first round, her project did improve in relevance and rigor to her baseline project, and results will likely improve in this regard in the second round.

The relevance and rigor of the project co-designed by Teacher C and SRI was improved in some impressive and important ways. Together they decided to follow a student design process of "Empathize, Investigate, Ideate, Prototype, Revise." The SRI partner said that this closely mirrored the process that industry takes. Although the teacher was familiar with this, he had not used it explicitly with students, as he now will do in this project. As noted in the collaboration section, the partner also was influential in make this more than a project building to specs, and instead added creativity by making it a design challenge. He also added in student choice: students would have to build with different variables per their choice, like building a vehicle capable of rolling over a bumpy road or one that could bear weight or travel through water. The object being for the car to go the farthest without toppling.

In the Project Design template designed by the researcher, there is a place to articulate "student self-management." SRI said he wasn't sure what to put, and Teacher C said they use a particular project management tool, called the Gatt tool, which is how student groups manage themselves, so he would put that in the space. In discussing this process, SRI was in agreement that this mirrors industry practice quite well, and they were pleased to discover a way to use this tool early on in the engineering pathway, with ninth-graders. The Gatt tool was then brought up by the partner with the next teachers. Again, this was something the teacher knew of, but had not used in his other projects with grades 9 and 10. In this way, teacher accountability to an effective practice was increased when collaborating with an industry partner, which as identified by Markett and Karpova as a benefit to educator-industry collaboration.

SRI also used the Project Design Template to articulate individual and group student responsibilities: Each individual student in a group be responsible for the design of and drawings

of a different vehicle part, and then communicate effectively as a group to make sure the parts all worked well together. The teacher had not thought to divide the project in this way, and it increases the individual accountability. SRI stated that this is often how it is done in industry and showed how students would be individually assessed on design drawings, with various views, including exploded views and assembly, as well as a group on other drawings (done using Inventor software).

Teacher C affirmed the process and said he felt this was all time well spent. “These projects can take long because they will meet many of my learning goals for students. I really think they are going to have fun with this, and I think there will be several ways that these projects allow for individual student differentiation. Some of my students take an engineering class in middle school, and they’ll be able to take the creative aspects of the project further and take on the more challenging tasks, but everyone will need to work well together. This is going to be good!” The partner said that he felt really good about the process. He was happy to be bringing more industry skills and standards to the projects, and that it was very helpful to have the template, me as a connector, and the fabrication lab manager to help work out the technicalities. He said he felt that none of these projects would have been possible without those, at least in the initial work with a new teacher. Again, this echoes the experience of Markett and Karpova, as well as other collaborators discussed in the literature review.

Teacher D: The rigor of this architectural model project was greatly improved through the partner collaboration. It now includes more design challenge choices, as well as the elements mentioned above, concerning Teacher C.

Teacher E: The rigor of this prosthesis unit will be much improved over the baseline project. There is now more authenticity, cross-pathway collaboration, and a more realistic way to build the hand model. As in the cases above, there are now different design challenges that students may choose, and there are plans for a public presentation, as is also the case in the projects above.

The table below summarizes the impact data by comparing baseline projects that met PBL Gold standards, with post-intervention projects. The number of teachers who thought this baseline project met each of the elements, according to their own assessment, (and as understood by me through their description) is indicated in the first column. The only essential element that all five teachers felt their best baseline project had met was "the focus on key knowledge and understanding derived from standards, and success skills including critical thinking/problem solving and self-management." Although 4 out of 5 teachers in the study thought their baseline projects had a challenging problem or question, "operationalized by an open-ended, engaging driving question," subsequent work on the Design/Planning tool showed that all five struggled (but ultimately succeeded with help from the partner) to articulate a driving question that met these criteria. The "Public Product" PBL requirement that students to create a product that is presented or offered to people beyond the classroom was present in only 40% of the baseline projects, and the elements of "Critique and Revision" and "Reflection"were absent. "Sustained inquiry", a process in which "students generate questions, find and use resources, ask further questions, and develop their own answers," was absent in these projects. Student Voice and Choice, which "allows students to make some choices about the products they create, and how they work" was an element present in 60% of the projects. The chart below indicates the

elements of the projects that met Buck Institute Project-Based Learning "Gold Standards," before the intervention, compared with the projects designed after the intervention. Furthermore, observation notes from the co-design planning sessions indicate that the use of the project design template by the teacher and partner as they designed the project helped ensure that the essential elements were met, as they repeatedly returned to the template to make sure areas were not missed. Observation notes indicate that this resulted in parts being added to the project, such as opportunities for critique and revision. The three teachers who were coached last used this tool more often and more effectively than the first two teachers, and their projects met more of the criteria for high-quality projects.

Essential Project Design Elements Checklist

"Whatever form a project takes, it must meet these criteria to be Gold Standard PBL."

Does the Project Meet These Criteria?	**Baseline Project As self-assessed by teacher and understood by coach.**	**This Project, as assessed by teacher and coach.**
KEY KNOWLEDGE, UNDERSTANDING AND SUCCESS SKILLS: The project is focused on teaching students key knowledge derived from standards and industry success skills including critical thinking/problem solving, collaboration, and self-management.	**4 out of 5 teachers said baseline project met requirement.**	**5 out of 5 post-invention projects met this requirement.**
CHALLENGING PROBLEM OR QUESTION: The project is based on a meaningful problem to solve or a question to answer, at the appropriate level of challenge for students, which is operationalized by an open-ended, engaging driving question.	**2 out of 5 teachers said baseline project met requirement.**	**5 out of 5 post-invention projects met this requirement.**
SUSTAINED INQUIRY: The project involves an active, in-depth process over time, in which students generate questions, find and use resources, ask further questions, and develop their own answers.	**0 out of 5 teachers said baseline project met requirement.**	**5 out of 5 post-invention projects met this requirement.**
AUTHENTICITY: The project has a real-world context, uses real-world processes, tools, and quality standards, makes a real impact, and/or is connected to students' own concerns, interests, and identities.	**3 out of 5 teachers said baseline project met requirement.**	**5 out of 5 post-invention projects met this requirement.**
STUDENT VOICE & CHOICE: The project allows students to make some choices about the products they create, how they work, and how their use their time, guided by the teacher and grade level.	**3 out of 5 teachers said baseline project met requirement.**	**5 out of 5 post-invention projects met this requirement.**
REFLECTION: The project provides opportunities for students to reflect on what and how they are learning, and on the project's design and implementation.	**0 out of 5 teachers said baseline project met**	**5 out of 5 post-invention projects met this**

	requirement.5	**requirement.**
CRITIQUE & REVISION: The project provides opportunities for students to give and receive feedback on their work, in order to revise their ideas and products or conduct further inquiry.	**0 out of 5 teachers said baseline project met requirement.**	**5 out of 5 post-invention projects met this**
PUBLIC PRODUCT: The project requires students to demonstrate what they learn by creating a product that is presented or offered to people beyond the classroom.	**2 out of 5 teachers said baseline project met requirement.**	**5 out of 5 post-invention projects met this**

In all cases, the initial project ideas were improved by working effectively with an industry partner in some key and notable aspects. One was in articulation of an open-ended and engaging driving question. These questions were usually provided by or edited by the partner. Another was that projects also tended to include more student choice with design challenges built in. A third was that the way the students worked through the projects mimicked industry more closely. More authenticity was built into the process, for example, by having students work in a group, then go apart for a period of time to do their piece individually, then come back together to reassess the pieces and overall design, etc. Instead of working in groups and assigning some individual work as homework, the process seemed to emulate more of a work setting, where teams plan together, then go back to their office or lab, but are working in proximity to check in as frequently as needed with the others. It was a subtle shift but I noted it, and the teachers commented on that also. The projects were also more authentic in that they included outside

review of their designs before the build, and a review of their design by mentors afterward. Because the partner was now very invested in the project since being involved in its design, he was more than ready to offer to get colleagues and himself to act as feedback mentors. This helps the teachers to include the key element of "Critique and Revision" in their projects, which were missing in all of the baseline projects, and it also provides that the project have a public aspect, also an element that had been missing from baseline projects.

The intervention, therefore, had a striking effect on the improvement of the problem of practice: that teachers do not know how to collaborate effectively with partners to create relevant and rigorous projects. As was described in the literature review, once a planning and communication structure is established, learning goals agreed upon, and a stance of relational trust is taken, project design will incorporate the strengths of each party, as each contributes ways in which to bring the project to a "gold standard." The projects created with partners after coaching were more relevant and rigorous, and the partners, as well as the teachers, felt that their collaborative process had been effective and satisfying.

Findings regarding Coaching:

The action research project relied on skilled coaching. Mistakes and adjustments were made. It was very helpful to analyze my coaching session notes and video recording to understand more clearly when a particular coaching stance was required, i.e., one that was more directive, more collaborative, or more facilitative going forward, and to strategize my next coaching sessions based on this reflection of my coaching. Increasingly, I was able to use probing questions more effectively to move teacher practice once I had taken time to review and

reflect ahead of time, which helped teachers to think more deeply about the project and to initiate improvements. The debrief sessions, after the teachers had collaborated with the partner in the initial co-design session, were especially important in moving teacher practice, as they constituted real-time, individualized professional development that helped the teachers to adjust course, ask follow-up questions of the partner, and to ultimately improve their understanding of the project in terms of organization and rollout, as well as to address any gaps in the essential elements of high quality projects for student learning. Because I realized early on with Teacher A that more coaching sessions were needed, and also that time is at a premium, I have concluded that some of the ground work in the first session could be done in a professional development setting, hopefully freeing up more time for an extra coaching session during the project planning and implementation.

Implications

The action research indicates that this is an area worth pursuing and investing in, as there were improvements in all areas: collaboration, management, and project rigor and relevance. Going forward, I plan to structure an initial in-depth professional development session for pathway teachers, and ask the teachers and partners in this study to participate in a panel discussion of what worked and what advice they would offer based on their experience. Teachers coming for professional development would be asked to read and reflect on articles with other teachers so that they have more time and are able to delve into the articles more deeply. I would then like to try to bring in partners shortly thereafter to co-design projects with teachers, and

embark on the individual coaching shortly thereafter. Once a teacher has effectively co-designed two projects, the could be tapped as coaches to expand capacity. I think the coaching would be more effective with this type of front-loading through group professional development, and this would also allow for additional coaching directly related to the project. I would also share these results and plan at a principals' meeting at the beginning of the year, so that they can help to support this work and understand the alignment of CTE work with the overall educational goals of Common Core.

Collaboration with industry partners kept teachers stimulated and energized. Projects designed were more explicitly relevant to the industry and to students, just as the literature review indicated. Teachers indicated that the extra effort to work with a partner was well worth the payback of having someone to help think about and carry the work. It resulted in teachers pushing themselves to create projects that were more relevant and rigorous. Partners indicated that they felt that having a district coordinator to help facilitate the partnership, as well as a process to use, was essential in the successful outcomes.

This study was limited to five teacher volunteers who believed that their projects could be improved with industry partner involvement. Although they did not initially have the skills to collaborate effectively or to build projects that met high standards, they did have the will and positive attitude that helped to make the intervention successful. On the other side of the equation, the industry partners had all been chosen by their companies to do the educational outreach, based on some of their personal qualities and experience. The intervention may not have worked as well as this not been the case.

We do not know, in this time of technological acceleration, what types of jobs the future will hold, but supporting teachers to create challenging, dynamic student projects that involve critical, creative thinking and skillful collaboration will certainly help to prepare students for their future work lives and lifelong learning.

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Exhibit A:

Working with an Industry Partner on a Project

Being an effective project partner:

o Be ready to explain your career pathway course progression and curriculum units and goals. Make copies of the Project Planning Tool and supporting materials (your unit plans, the school's bell schedule, etc. as outlined in planning tool) ahead of time, for both you and your partner. If you choose to use laptops, great, but have hard copy backups.

o Be prompt, and if the partner is coming to you, make sure they have the address and parking information. Meet them at the front office and walk them to your room or meeting space.

o Ask the partner about himself/herself and their role in the company. Share your own background. Establishing a friendly relationship is important.

o Remember to show the partner appreciation for partnering with you and your students. They are often donating their time.

o You will probably know if the partner is coming to you with an idea, or if you will be presenting a project idea, but either way, remember that the project needs input from both of you. Ultimately you need to make sure that it meets learning goals and that the time spent is proportional to learning experience. Be flexible where you can and remember that these experiences with outside entities are often the most memorable and formative for students! Students report many benefits beyond the project itself!

o Try to be flexible: the exact project dates you desire may not work for the partner, so be prepared with ways you might be able to re-arrange your units if necessary.

o Ask clarifying and probing questions, solicit ideas. Be honest if you have concerns and take time to work through them.

o Use the Planning Tool to develop concrete shared understanding and agreements. This will cover shared goals, the timeline, the communication processes, kickoff and culminating events. Will the partner come to speak to kick off the event, for example? Will students present their projects to the company? Others? Medium: video? PowerPoint? Webcast? In person, with props?

o Negotiate the project parameters: If you are not sure and need more time to think about integration of the project, ask for a few days to think about and get back to the partner. Make sure you before you commit to a project.

o Pay particular attention to logistics. If there is a study trip connected to the project with partner, make sure you have the logistics down, including bus, parking, lunch, what students bring with them, and what you need to do ahead of the trip and after the trip. If the fabrication lab will be utilized, make sure to schedule that time with the fab lab manager, and if necessary,

the partner. The devil really is in the details! Don't leave arrangements until the last minute, as this can derail the project.

o Avoid using acronyms. Use plain English, not "eduspeak."

o Don't refer to Period 5, etc.: make plans in terms of times, and pay attention to school calendar/activities that will impact dates.

o Honor your obligations.

o Stay in touch and let the partner know right away if you need to make a change, and indicate that on the Planning Tool once agreed. The partner will likely be more than happy to help out with providing students with some formative and summative feedback on the project, and may be able to recruit some colleagues. That is the beauty of co-creating a project; they are more invested in seeing the results!

o Once completed, take time to thank the partner, and get students to write thank you notes.

o Schedule a phone call or visit to reflect on the project and what you might do differently next year. (Yes, next year! You will want to leverage this investment of time, and so will your partner.)

o Keep your sense of humor and humility throughout! We are all learners!

Exhibit B: Project Design/Implementation Template (Landscape orientation, figuring out how to attach it here without messing up the rest of the document!)