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Empowering Students Through Gold Standard Problem-Based Learning (PBL) in Technology and Engineering Education

Session 1: Innovation in the Classroom

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"We come from the earth, we return to the earth, and in between we garden." Alfred Austin

Setting the Stage

The epigraph is attributed to former British Poet Laureate Alfred Austin (1835-1913). It summarizes how we humans, in our short life span, are at our core gardeners. Some of us do it literally and some of us do it metaphorically. Regardless of the type of garden that we grow, we are destined by genetics and evolution to be makers and doers, builders, inventors and problem solvers - a species that is creative, resourceful, and ingenious in how we make our gardens grow (Burke & Ornstein, 1995).

If we are destined to be such creatures then it also makes sense that we would learn best to grow our gardens by doing - to get our hands dirty, if you will. Such approaches to learning have had many names over time including exploratory learning, experiential learning, design-based learning, project-based learning, and problem-based learning (Larmer, Mergendoller & Boss, 2015; McDowell, 2017). One of the defining characteristics of technology and engineering education (TEE), and all its predecessor programs such as industrial arts and manual arts is that the best approach to learning is through the doing of processes and the making of things (Moye, Dugger & Starkweather, 2014). If humans are inherently inclined to be the gardeners previously described, it would also make sense that all content at all levels should also be taught with the learning by doing approach. And that is why since at least 2016, the authors have been teaching a graduate level course called Teaching Across the Curriculum Using Problem-Based Learning. This course is a part of a summer menu of courses, called institutes, that use a deep dive approach where students must do 20 hours of pre-institute readings, followed by a 40-hour week of intense real-time class work, and conclude with a 30-hour expectation of creating a unit or units of instruction and applying what is learned in the institute in their own classroom. Our institute is taught in a face-to-face format at our university but also involves at least one field trip to a Montessori Academy and, when possible, an alternative high school. Guest speakers are also brought in including book authors, teachers from all grade levels and content areas who

have experience using problem-based learning (PBL), school administrators who support and nurture the use of PBL, and experts on PBL from the United States and other countries. The end artifact that all students must produce is a PBL learning module that is appropriate for their subject area, their students' developmental level, and the curriculum that is used in their classroom. In short, our goal is to get the educators comfortable with PBL by helping them to take their first steps toward using PBL in their classrooms.

The preliminaries for this institute began a few years earlier in 2014 or 2015 when Dr. Warner began teaching half-day and full-day workshops on the subject to local education programs such as the Chester County Intermediate Unit. Those short professional development activities would eventually lead to the first full iteration of the institute in 2016. Dr. Warner taught those first versions on his own. However, in the 2018/2019 academic year he began working with Dr. Miller to meet on a regular basis to plan a new and improved version of the institute. This effort began, in part, as an outgrowth of Dr. Miller's doctoral work. In the summer of 2019, Dr. Miller became a guest co-instructor with Dr. Warner in the first iteration of the current design for the institute. The "guest" co-instructor label was used because Dr. Miller was also fulfilling an internship expectation for her doctoral degree. In subsequent years, Dr. Miller would become a full co-instructor for the institute because of her becoming an adjunct instructor at our university. She is now the lead instructor of the course. The early institutes enabled us to refine and expand our own understanding of PBL as well as further develop our repertoire of instructional approaches and resources that would work with teachers from across the various curriculums and instructional grade levels. They also allowed us to develop as an instructional team.

The instructional approach that was most used toward teaching manual arts, industrial arts, technology education, and now TEE could, on the surface, be identified as project-based learning (PBL). Scherer (2022, June) provided an overview of project-based learning when he wrote:

> At its core, project-based learning is a method for facilitating learning made up of three ideas, which we can define clearly, even if their sum is complex:
>
> - Project: An individual or collaborative endeavor designed to accomplish a goal.
> - Based: To provide the context or foundation for something.
> - Learning: The acquisition of knowledge or skills through practice, experience, study, or being taught.
>
> At a high level, project-based learning is the acquisition of skills or knowledge through the process of engaging in an individual or collaborative endeavor that accomplishes a goal. (para. 9)

Our planning for the first institute that we taught as a team took about a year. Our research and planning for a redesign of the institute occurred through weekly meetings leading up to the Summer of 2019. After looking deeper into the nature of PBL, our first decision for the institute was to change the "P" in PBL from project to problem. Larmer et al. (2015) wrote that they considered the differences between problem based and project-based learning to be "academic and arbitrary" (p. 30). Our rationale for making that change is that we felt the word "project" had too much of an implied predetermined finished artifact. We wanted to avoid the stereotype of telling the students "Here are the plans, now make some artifact that looks just like the ideal representation I have put before you." With this decision out of the way, we decided to adopt the concepts of Gold Standard PBL as put forward by Larmer et al. (2015) and Boss and Larmer

(2018). The specifics of what defines Gold Standard PBL from generic PBL will be discussed in later sections of this paper.

Our second major decision was to appeal to not only technology and engineering education (TEE) teachers, but to the entire range of content areas and grade levels in the schools. This decision opened the marketplace of potential students for the institute. The contemporary literature and research on PBL were supportive of this approach to teaching and learning being appropriate for all learners, in all developmental levels, and in all subject areas (Wolk, 2022). Thus, it enabled us to present to graduate students, most of whom were classroom teachers seeking some form of professional development experience, exposure to PBL as a pedagogy which had universal application. This decision also directed the name of the course to become "Teaching Across the Curriculum Using Problem-Based Learning."

What is PBL?

According to Larmer et al. (2015), in a formal sense PBL has a history that extends at least back to 16th century Italy and the use of "progetti" (or projects) through which developing architects and sculptors were trained in the respective fields to express form and function toward a building or a piece of art. These early efforts set the stage for our modern interpretation of PBL as an approach to learning that is driven by the process of inquiry. PBL uses problem scenarios to encourage students to participate in the learning process. Typically, the teacher selects the task and supports or facilitates the process, but the students are expected to explore the task, claim their present understanding, examine their knowledge and skill gaps to decide what new information and skills they need to appropriately address the task and resolve the problem.

Ideally, PBL is an inquiry process undertaken by students in which they seek to resolve questions and uncertainties about complex life situations. Students learn from and build upon each other's questions, are open to different points of view, listen to and respect each other's' ideas and work collaboratively towards problem resolution and reasonable conclusions (Barell, 2007; Wolk, 2022).

A key dynamic of PBL is that the curricula should be organized around a problem. That problem, or the scenario, should be appropriately complex and should be sufficiently open-ended to allow for a variety of responses or possible solutions. Students primarily work in groups, though PBL can provide opportunities for both group and self-directed learning. The teacher's role becomes that of facilitator or guide. Students should have voice and choice and, thus, should direct the lines of inquiry and methods employed to investigate the problem and its possible solutions. The inquiry requires students to draw on existing knowledge and to also identify their required learning needs (Larmer et al., 2015; McDowell, 2017; Scherer, 2022; Wolk, 2022).

Teachers should select real life situations that have no 'right' answer as the organizing focus for learning. This is done to help students learn that often solutions to life's problems require compromises between and among conflicting variables. Rarely does an answer to a real-life problem have yes or no, black or white simple answers. Often, the learning that students do in a PBL experience is achieved through their realization of what they do not know and what they need to learn to address the problem before them. This learning typically must precede the

development of viable solutions. Students then gain new information that is enduring and transferable because of their intrinsically motivated self-directed learning. The dynamic of PBL experiences that are structured this way leads to the development in students of judgment-based decision making, and problem-solving capabilities (Larmer et al., 2015; McDowell, 2017; Scherer, 2022; Wolk, 2022).

Dolmans et al (2005) argued that "PBL has the potential to prepare students more effectively for future learning because it is based on four modern insights into learning: constructive, self-directed, collaborative and contextual" (para. 2). The authors then went on to elaborate on each theory. Constructive theory posits that students use their prior knowledge as a foundation for building new knowledge. Self-directed learning theory is based on the idea that, given the right type of learning environment, students will initiate and direct their own learning processes. The collaborative learning theory asserts that learning is encouraged and enhanced when it takes place between and among two or more learners. Finally, contextual learning theory argues that learning is best facilitated when the learners are engaged with material and activities that are relevant to their world and that are appropriately challenging for their developmental level. Contextually relevant problems are more likely to stimulate curiosity in students, encouraging them to actively explore and seek out new evidence. In short, PBL puts modern learning theory into practice.

PBL also refocuses on the process of learning rather than the product of knowledge acquisition. On this matter Eisberg (2018) wrote:

> By focusing on PBL as the process of learning and the application of knowledge, students become more clear on the expectations for learning outcomes, which leads to higher quality products. But if too much of the focus is on the product itself, it can be a distraction from what the true intent of the project is… the learning! (para. 1)

In PBL there is a change of focus from assessment of outcomes to self-evaluation and peer critique. Wolk (2022) defined this aspect of PBL as changing from an assessment approach to teaching with a feedback mindset. The teacher's appraisal tools of student work are more in the formative instead of the summative realm. He elaborated on this concept of feedback's importance when he wrote:

> Assessment is not just done at the end of the project or unit but is an inherent part of teaching every day. When PBL teachers are zipping around the classroom helping students with their projects, they are assessing as they teach. A key part of that assessment is giving students feedback as they do their work. If we want students producing their highest-quality work then we need to: 1) have them do the work in the classroom; 2) give them feedback as they progress; and 3) as Ron Berger ('2003'[sic]) advocates, show examples of excellent work, teach them what quality looks like, and have students critique project work. (para. 35)

Why Use PBL as a Teaching Tool?

An educator might wonder why one would want to embrace PBL over traditional expository forms of teaching. Many teachers might also proclaim that they do not have time for PBL in an already overcrowded schedule that is trying to address a long list of academic standards. In response, it is important to remember that education standards represent the "what" of school and

PBL is a "how" to achieve those standards. Multiple studies at various grade levels, content areas, and contextual settings have shown that teaching with PBL results in student learning levels at least as good as if not better than traditional teaching methods (Larmer et al., 2015; McDowell, 2017; Scherer, 2022; Wolk, 2022). Previous passages have provided indications of some of the benefits of using PBL over more traditional forms of pedagogy. A summary of those benefits includes:

- It is harmonious with modern learning theories
- PBL provides opportunities for addressing both the affective as well as the cognitive growth needs of all students
- It facilitates authentic learning as well as authentic assessment through an emphasis on feedback
- PBL provides a platform for developing liberally educated minds – PBL draws from all fields of content and from across the total human experience
- The development of communication and interpersonal skills through PBL experiences help students understand the importance of being able to relate their knowledge and thus provide plenty of opportunities for transference of knowledge across and between content areas
- Responsibility remains with the students for analyzing and presenting evidence in appropriate ways and in support of their own response to the problem and thus helps to develop life-long learning practices in students

It should also be noted that the presence of PBL, and its variants, is more prevalent in the schools than some might assume. Scherer (2022) observed

> PBL is already in schools, hiding in plain sight in the elective classes and career-technical education (CTE) programs such as theater, art, music, journalism, robotics, engineering, agriculture, and more, that typically operate at the periphery of the traditional academic experience (Mehta & Fine, 2020). Perhaps because these classes are rarely subject to standardized testing, their teachers and students have flourished as long-term PBL practitioners. (para. 46)

This existing presence of PBL means that there are already practitioners in the schools, TEE teachers for example, who can serve as guides to those teachers who are making the shift to PBL. The challenge will be to make certain that both the existing practitioners and those who are making the shift are both aspiring toward PBL that has a common structure and end goals. One approach that has great acceptance is Gold Standard PBL.

Gold Standard PBL

Consider modern-day Olympic games. Thousands of athletes from hundreds of countries process into the opening ceremonies as years of hard work and dedication are put to the test. While there are hundreds of individual events, there is only one gold medalist for each event. Yet every athlete from every country has devoted their lives toward striving for that gold medal. Despite the same goal, possibly similar effort, and identical regulations, only one athlete will obtain the gold, all others will simply have set the aspiration and come away with the experience. Similarly, Gold Standard PBL is the aspiration for all PBL experiences. Built upon the foundational elements of how students learn best, Gold Standard PBL combines research-based practices with classroom-proven methods for teaching and learning. Gold Standard PBL is for educators the "North Star to shoot for and approach through problem solving, practice, and reflection" (Larmer

et. al, 2015, p. 34). This goal combines seven essential design elements to best help students develop important learning concepts and skills.

The seven essential project design elements of Gold Standard PBL are: challenging problem or question, sustained inquiry, authenticity, student voice and choice, reflection, critique and revision, and a public product. While any one of these elements represents best practices for the classroom and solid methodologies for teachers to consider in curriculum design, they do not represent a menu from which to pick or choose. Rather, a synergy exists within the elements of Gold Standard PBL wherein the elements culminate in something that is more powerful than the simple sum of its individual parts.

Challenging Problem

Rather than a standard or objective, the organizing structure for PBL is a challenging problem or question for students to grapple with as they develop new ideas and skills. This problem is instrumental in the classroom as it provides students with the motivation to learn new information as well as a purpose to their learning. Rather than developing new knowledge and skills simply to remember it or in case they need to recall it later, the understanding developed in PBL experiences is targeted toward immediate use within the problem or question. Research demonstrates that use of the knowledge during its mastery shows promise of students becoming more likely to be able to use and apply that knowledge later in new situations (Brown et. al, 1989). Studies also show that when students see information as useful and meaningful, it is much more easily recalled later (Bransford et. al, 2000).

While the benefits of providing a problem or question to frame learning is clear, the challenge that students encounter in addressing that problem or question itself is important (Hattie, 2012). Too difficult or easy of a challenge can both present situations where students become disinterested and unlikely to persist in their learning. Gold Standard PBL encourages educators to find the happy medium, the "Goldilocks" challenge level for students. Elements that contribute to the difficulty of the problem include the complexity of the academic concept, the problem structure, and the complexity of the procedures or steps necessary to solve the problem (Blumenfeld, et. al, 1987).

Within the summer institute, the goal is not only to educate teachers about the elements of PBL, but also to guide them through their first Gold Standard PBL experience. Intentional thought and planning were dedicated to ensuring that each element of the framework is present in the experiences, discussions, and the post-institute assignment that participants complete. The element of a challenging problem comes in the form of the teacher's own experiences within the educational system at large. Early course discussions include reflection on the current challenges within their own classroom, school, district, and the educational system as a whole.

Sustained Inquiry

John Dewey is an instrumental figure across educational theory and practice. He suggested that knowledge and principles are not easily accessed by students, rather they "must be wrested from nature by an active and elaborate technique of inquiry" (Dewey, 1920, p. 32). The point of the first element, the problem or question, is to launch students to that point of inquiry and sustain

that stage for a prolonged time in the PBL experience. The term inquiry has its roots in the Latin words of in, meaning into and quaerere, meaning to seek. When teachers lead their students to a point of inquiry, they are inviting students to act and seek knowledge, meaning, and answers within their learning. This isn't simply finding an answer from existing material, it includes asking their own questions, investigating, interviewing experts, gaining new experiences, and coming to their own new conclusions. These skills not only develop learning within the PBL experience or unit, but they also transfer to essential skills for college, career, and life (Larmer, et. al, 2015).

To complete the experience and earn credit for their work, graduate-level participants address a problem plaguing their own professional practice. Given that PBL has many benefits for students, teachers, and school systems, the task is to address incorporating PBL within their own place of practice. Institute participants are presented with two options for their final course assignment. One option is to design two units of instruction for their own classroom that incorporate the elements of Gold Standard PBL. This is the option that is chosen by most participants due to a variety of reasons including deadlines for district-level reimbursement of graduate credits and the feasibility of making curricular changes on short timing turnarounds. The second option is that participants develop one unit of Gold Standard PBL instruction that will be implemented within their classroom within the first month of the new school year. Participants that choose this option are then asked to provide evidence of classroom implementation including documentation of student work and reflection on the overall experience. This final assignment provides the sustained inquiry element for the institute. Each participant is tasked with questioning what this level of PBL engagement would look like within the context, constraints, and intricacies of their own place of practice.

Authenticity

The necessity for educational experiences to be real-world and genuine has attention well beyond the confines of PBL. Research ties authentic learning to increased achievement and motivation (Blumenfeld, et. al, 2006; Brophy, 2013). Key differences exist in classroom experiences that exist within the bubble of a sterilized classroom experience, those that encourage students to pretend to do real-world tasks, and those that empower students to take part in authentic and meaningful activities.

Classroom learning can be authentic in four different ways: context, task, impact, and at a personal level (Strobel, et. al, 2013). While context (projects themselves mimicking real-world results), task (use of authentic tools and processes), and impact (experiences where students can see real-world results and change) may be easier to understand and make use of, personal authenticity may require deeper exploration. Personal authenticity calls for experiences that connect to a student's own concerns, interests, or sphere of involvement. These are understandably more challenging as this may mean a different thing to every learner on the class roster. How can this be achieved or even set as a goal for an educator? The next essential design element of PBL, student voice and choice, plays a key role in empowering students to bring their own personal authenticity to the table.

Authenticity is accounted for within the final course assignment in that teachers are creating actual units of instruction that fit within their place of practice, their own content area, and with their own students. The task makes immediate use of the exact tools and processes that teachers have been learning about and observing throughout the institute. Beyond this, the task empowers and engages teachers in an immediate chance for authentic impact on not only their students but also themselves as an educator. Rather than work within a specific case study or assigned content area or grade level, teachers are staying grounded within their own classrooms and experiences.

Student Voice & Choice

Schools have long educated students through a series of lectures, activities, and assessments meant to deliver information and determine whether that delivery was effective or not. Within PBL, these prescriptive exercises are largely replaced with situations where students are given the freedom to make their own decisions and judgements. A foundational element to the development of PBL is John Dewey's idea of what he called the cognitive act or the act of thinking. Dewey brought light to the iterative nature of students encountering an issue, planning a new solution, attempting that solution, and reflecting upon their findings. Dewey believed that one of the most important roles of a teacher was to design and place those issues or obstacles into the hands and minds of his or her students. Within this context of learning, Dewey encouraged teachers to become a partner or guide within the learning process where students were independently discovering new concepts and skills (Dewey, 1938; Dewey & Small, 1897). Gold Standard PBL further stresses the need for students to be capable of finding themselves and their interests within the problem or project. This personalization is not possible in overly prescriptive class activities. Within PBL, educators must find ways to design intentional moments for students to take a problem or project in any number of directions based on student experience and insight.

It would be incredibly misguided and hypocritical to lead an institute on PBL that concludes in students writing a prescribed paper, enacting PBL within a hypothetical classroom, or demonstrating understanding on an objective final exam. Rather, there must be opportunities for participants to reflect, consider, and find themselves within PBL. Student voice and choice is provided to participants in a variety of ways. The first example is found within the two options provided for completing the final assignment. Whether someone decides to complete two units for use down the road or one unit for immediate implementation, the participant themselves is the person best suited to make the decision that is right for them. On a deeper level, there is a vast depth to the level of student voice and choice provided in that the PBL units can occur in any grade level, course, or content that is selected by the participant. A preexisting unit may be altered to include all elements of Gold Standard PBL, or an entirely new unit may be developed from the ground up. In past institutes, teachers from within the same school have chosen to collaborate on unit experiences, or teachers of different grade levels from within the same district have chosen to use one another's class as part of the public audience for their designed units. In providing such open and flexible directions for the final assignment, intentional space is left for student voice and choice to empower and enrich the learning experience of participants.

Reflection

It is incredibly difficult to discuss the role of reflection in teaching and learning without referencing the ideas of John Dewey. He is often credited with writing, "We do not learn from experience. We learn from reflecting on experience." Though that exact quote does not show up in any of his writings, it perfectly summarizes his philosophical perspective in such works as *How We Think* (1910) and *Education and Experience* (1938).

Costa and Kallick (2008) observed that,

> The human species is known as *Homo sapiens sapiens*, which basically means 'a being that knows their knowing' (or maybe it's 'knows they're knowing'). What distinguishes humans from other forms of life is our capacity for metacognition - the ability to stand off and examine our own thoughts while we engage in them. (p. 23-24).

If one of the primary differences between humans and all other living creatures is the idea that we can think about our own thinking and knowing, does it not follow that educators should be fostering, growing, and developing this skill in students? To further defend the importance of reflection as a teaching and learning tool, reflection about one's own thinking, better known as metacognition, ranks 14th in the list of influencing factors on student achievement by John Hattie (2012). Rather than get lost in what can seem amorphous and messy as compared to more traditional classroom methods, PBL relies on reflection at several stages and levels. When reflecting on outward things, students are considering the tasks, progression, and limitations of their solution. When reflecting inward, students increase awareness of their own learning, problem-solving strategies, and can use these reflections to make better choices in future situations (Larmer, et. al, 2015). This reflection is not always obvious or natural to students, educators must purposefully plan and prepare students for making time for reflection and metacognitive thinking.

One level at which the institute purposefully demonstrates the practice and need for reflection is within the designed schedule for the week. Each day begins with reflection on the previous day's events including key concepts and principles. Each afternoon, participants are provided with time to consider their current inner thoughts, questions, and concerns and discuss these in small or whole-class groups. From the first morning of class, each institute participant is provided with a small pocket notebook and encouraged to intentionally journal throughout the week. This journaling provides an opportunity to document thoughts large and small that can be revisited or reconsidered later in time. Not only is this encouraged during the week, both instructors stress the importance of this practice in their daily lives and show participants their own mini notebooks filled with a variety of thoughts, questions, and reflections.

Beyond this, there are individual sessions or lectures built into the schedule that prompt participants to be reflective of their new information and the ways in which it fits into their current place of practice. For example, there is a session on the resultant paradigm shift of PBL wherein the role of a teacher is drastically different from traditional school. There is also a session on taking the first bite of the proverbial elephant which prompts teachers to consider where they currently are in their PBL understanding and to map out the incremental changes that would be necessary to get them from where they are to where they want to be in using PBL

techniques with students. Reflection is modeled, discussed, and assigned to participants as a key element not only of Gold Standard PBL but also of deep and meaningful learning.

Critique and Revision

Not all assessments are equal. Over the past 25 years, many researchers have argued the power of formative assessment to enhance and solidify student learning (Hattie, 2012; Black & William, 1998; Schroeder, et.al, 2007). In writing about formative assessment and evaluation, Hattie (2012) elaborates that the role of being a student goes beyond simply following teacher directions but to also become the master of their own learning. "This includes evaluating their own progress, being more responsible for their learning, and being involved with peers in learning together about gains in learning" (Hattie, 2012, p. 88). While formative assessment can be performed in a variety of ways, Gold Standard PBL explicitly calls out critique and revision as one of its essential elements. Once again, a key aspect of including feedback and critique in the classroom is teaching students how to appropriately and productively give effective feedback to others. Rather than being a negative result, feedback and critique should be emphasized as a normal aspect of learning and creating new things. This idea is one of many included as part of having a culture of craftsmanship and excellence within classrooms (Berger, 2003). Additionally, PBLWorks has published an abundance of tools and strategies that teachers can use to develop good critique behaviors in students including across single or multiple artifacts. Ron Berger, often viewed as an expert in student feedback, suggests that for critique to be constructive it must be kind, helpful, and specific (Berger, 2016). Self-assessment and peer review are vital aspects of the rich critique and revision that takes place in Gold Standard PBL.

In addition to learning a variety of frameworks, examples, and strategies for review and critique, institute participants are faced with daily opportunities to discuss, provide and receive critique, and revise their thinking on incorporating PBL within their classrooms and how it might look. In addition, both institute instructors and experts' model self-assessment through the sharing of their own journeys with PBL including both successes and failures. What results is an institute culture that embraces mistakes, failures, and opportunities for learning from feedback rather than a fixed, results-oriented mindset. This culture development allows for more open and rich conversations that include constant feedback and critique between participants, instructors, and guest experts.

Public Product

Most school assignments are viewed by students, the teacher, and occasionally a parent. Rarely is student work viewed, assessed, or appreciated by a larger audience. Gold Standard PBL emphasizes the opportunity for students to have a voice and impact beyond the confines of the school environment. Not only is this a more authentic and impactful experience for students, it also increases student motivation to perform at a high level. Their work will see the light of day, be assessed by experts, and have a larger audience than their typical experience. Not only does this increase student motivation to do well, it also increases their perception that the work is worthwhile (Larmer, et. al, 2015). A sense of pride in accomplishments does much to the identity and self-esteem of students.

In addition to the many student and teacher benefits, the school system also benefits by involving the larger community in student outcomes. When the boundaries of the school are opened and outside experts are engaged, there is great potential to also increase overall support and engagement with the school system at large.

A public audience for PBL can be modeled and demonstrated in a variety of ways and quite a few are implemented with institute participants. Within the course, teachers are exposed to outside experts that not only share about their own PBL experiences, but also give feedback and guidance to the participants on their own current conceptions of how PBL might work in their place of practice. Targeted planning occurs toward which experts, tours, and speakers are asked to join the institute each year. Typically, it is ideal for participants to hear from private and public schools, a variety of content areas and grade levels, as well as a mix of classroom teachers and administrators. In this way, teachers can each find a bit of themselves and their place of practice in the speakers. Additionally, the public audience with whom they share their ideas have a wide range of perspectives and feedback that they can provide. The speakers chosen for the institute also represent a combination of directly engaged PBL experts, and those from a variety of what the instructors term PBL-adjacent approaches such as Mass Customized Learning (MCL) and Montessori education. Past speakers have included superintendents, headmasters, classroom teachers, career and internship professionals, higher education professors and a published author on PBL. Students have engaged with these experts via Zoom, in-person lecture and discussion, and on-site tours of innovative schools and learning environments.

There lies an ultimate public audience for the results of the institute. In the end, the future students of the classrooms of each institute participant are the larger public audience of the final assignment. It is with these students in mind that PBL experiences are developed. Additional attention is given during the institute toward communicating and educating the larger stakeholder group on this change to PBL. Participants are equipped with ways to inform administration, parents, and other teachers about their new adventures in PBL and changes that they should expect within the education of students. The seventh and final element of Gold Standard PBL is incorporated in the summer institute through a variety of techniques including expert guest speakers, tours, and planned stakeholder communication.

Technology and Engineering Education's Attainment of Gold Standard PBL

For as long as there have been formal hands-on forms of education, there has been some type of PBL occurring. As noted in the opening section of this paper, the use of "progetti" was one historical example. In the systems of apprenticeships used in medieval Europe, the apprentices would work on first small and then increasingly larger aspects of the artifact being produced by the master. This progression of the apprentice completing increasingly larger and more complex parts of the project or artifact could be considered a type of PBL (Bates, 2015). The industrial arts curriculum of the 20th century would rely heavily on the making of projects and artifacts using the materials of industry such as wood, metal, ceramics, and plastics. Based on the expectations of what would be defined as Gold-Standard PBL, traditional industrial arts, technology education, and even TEE projects would, perhaps, be better defined as product-based learning, where the product was the focus of the exercise and not the learning that occurs along the way (Eisberg, 2018). Occasionally, progressive industrial arts programs would appear which

would investigate technology beyond the materials of industry as their focus. Instead, they would use scenarios from the broader world as the catalyst for solving technological problems, understanding the history of technology, or dealing with some other issue through the use or modification of a technology (Foster, 1994). Examples of programs that would more closely approach Gold Standard PBL include The Maryland Plan of the 1970s (Maley, 1969) as well as the design-based curriculums in other countries such as Great Britain (Kimbell, et al, 1991) and Australia (Williams & Williams, 1997).

Earlier it was noted that Scherer (2022) identified a whole host of content areas that were already using some form of PBL. His list included areas of study such as career and technical education (which fits perfectly with the heritage of the apprenticeships written about earlier) and other content that is right out of the TEE curriculum including such things as "robotics, engineering, and [other] elective classes" (para. 46). The question we must ask is even if PBL is present in a school, even in a TEE program, is it being modeled in a Gold Standard configuration?

The making and doing nature of progressive TEE often lends itself to sustained periods of student inquiry and exploration. Furthermore, there is an authenticity to the subject matter that is deeply rooted in real-world approaches, topics, and solutions. Unfortunately, TEE's attainment of Gold Standard PBL becomes more difficult to defend as one progresses further down the list of the defining characteristics of PBL. Historically, making and doing have been a keystone practice of the field, even while the ways in which it is used in the classroom has slowly shifted from "producing pre-designed objects focused on developing industrial skills to creating innovative solutions to open-ended design challenges" (ITEEA, 2020, p. 76). It is within these innovative and creative approaches to making and doing that student voice and choice has increasingly become part of the landscape of TEE classrooms. This represents a move away from the traditional approach toward the development of industrial skills through the recreation of a prescribed set of plans. That approach left little room for student voice or choice, much less any type of decision at an authentic level.

The final three components of Gold Standard PBL, reflection, critique and revision, and public product, are the most difficult to consistently find achieved within TEE classrooms. The term "reflection" shows up only five times within the field's standards document. Only one time in the document does the use of the term deal with student reflection. Lumped into the practice of Optimism in TEE, one example is provided with a blanket statement that the teacher utilizes discussion to "solicit student reflections on the process" of developing a rooftop farm in a middle school technology education class (ITEEA, 2020, p. 82). Meaningful reflection requires thoughtful planning and teacher support to model, guide, and equip students to reflect on their own actions, processes, and thoughts within a learning experience (Turns, et. al, 2014). Similarly, critique and revision tend to happen at the same superficial level. The Standards for Technological and Engineering Literacy (STEL) document contains one example of student use of critique without explicit mention of using that critique with any revision in mind. When considering critique and revision two pitfalls emerge in the field. Either the only assessment is teacher assessment without peer feedback or students are assessed and critiqued without the opportunity to make revisions on their work. Finally, the presentation of a student-made product to a public audience can be a category that shows inconsistent use from one classroom to the next. Admittedly, there are various levels of what can be considered a public audience. Larmer,

et. al, (2015) suggest that a public display includes any audience beyond the classroom. This could be anything from inviting the neighboring teacher into the room to inviting an industry expert to interact with and assess student work. As with much of education, that continuum can result in vastly different student experiences and results. The presentation of the end results of the PBL experience to an outside audience, the public product, is essential to raise the PBL experience to the Gold Standard level.

In reflecting on their own visits to self-proclaimed PBL classrooms, Mehta and Fine (2020) found those classrooms to be, "aspirational places striving to enact deep learning, but most tended to have the familiar 'aspirations gap' with respect to achieving their visions" (p. 51). One could argue the same about TEE's attainment of their PBL goals. While the field is well poised to master PBL, for several reasons including the foundational authenticity of making and doing and the lack of standardized testing in most states, we fall short of the aspiration of Gold Standard PBL. One could say that TEE is currently at the Olympic games but achieving at a level closer to that of a bronze medal.

Closing Argument

Gold Standard PBL presents seven elements of a high aspirational goal for teaching and learning. Based upon the best research and classroom-proven practices, its implications for change in schools run deep. Not only does it require that students learn and think differently throughout the learning process, it requires a paradigm shift in the mental model of what it means to be a teacher. Mehta and Fine (2020) reflect on this paradigm shift in their own exploration of the potential for PBL to lead to deeper learning.

> "*How can teachers learn to embrace such a different notion of what it means to teach, given the longstanding dominance of beliefs and practices that run counter to it?* In addition to establishing a shared vision of what 'gold' looks like, this is a critical question for aspiring progressive, particularly project-based schools to answer – and our observations suggest that the strength and 'thickness' of those answers can make all the difference." (p. 79)

The summer institute serves as a model for professional learning of preservice and in-service teachers around the topic of PBL, specifically Gold Standard PBL. The research demonstrates the transformative potential of problem-based learning (PBL) to equip all teachers, but especially technology and engineering educators, with the pedagogical skills necessary to foster innovative and critical thinking in their students. The extent to which the institute teaches about and models the culture of Gold Standard PBL leads educators to have meaningful reflection about how they teach. It also raises the question of if and how fellow teachers can serve as PBL guides to their colleagues within their schools. This is a question that all teachers should consider as PBL becomes more widely acceptable as a pedagogy in all grade levels and all content areas.

We began this journey through the epigraph of Austin as gardeners, tilling the fertile ground of human potential. Through problem-based learning, we've developed not just knowledge, but the very tools for lifelong learning. Let the seeds of curiosity continue to germinate. Problem-based learning empowers learners to do just that, transforming students from passive recipients of information to active cultivators of their own intellectual growth. The future of education is not a set curriculum, but a vibrant garden, nurtured by PBL, where every student can flourish.

References

Barell. J. (2007). *Problem-based learning: An inquiry approach*. London: Sage Publications.

Bates, T. (2015). *Teaching in a digital age. Guidelines for designing teaching and learning. Vancouver: Tony Bates Associates Ltd*. https://opentextbc.ca/teachinginadigitalage/chapter/3-5-apprenticeship-learning-by-doing-1/

Berger, R. (2003). *An ethic of excellence*. Heinemann.

Berger, R. (2016). Austin's Butterfly: Models, Critique, and Descriptive Feedback. El Education: https://www. youtube.com/watch.

Black, P.J., & William, D. (1998). Inside the black box: Raising standards through classroom assessment. *Phi Delta Kappan, 80*(2), 139-148.

Blumenfeld, P.C., Kempler, T., & Krajcik, J.S. (2006). Motivation and cognitive engagement in learning environments. In R. K. Sawyer (Ed.) *Cambridge handbook of the learning sciences.* New York: Cambridge University Press.

Blumenfeld, P.C., Mergendoller, J. R., & Swarthout, D. W. (1987). Tasks as heuristics for understanding student learning and motivation. *Journal of Curriculum Studies, 19*(2), 135-148.

Bransford, J., Brown, A., & Cocking, R., Eds. (2000). *How people learn: Brain, mind, experience, and school.* Washington, DC: National Academy Press.

Brophy, J. E. (2013). *Motivating students to learn.* New York: Routledge.

Brown, A. L., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18,* 32-41.

Boss, S. & Larmer, J. (2018). *Project-based teaching: How to create rigorous and engaging learning experiences*. Alexandria, VA: Association for Supervision and Curriculum Development.

Burke, J. & Ornstein, R. (1995). *The axemaker's gift: A double-edged history of human culture*. New York: Grosset/Putnam.

Costa, A. L., & Kallick, B. (Eds.). (2008). Learning and leading with habits of mind: 16 essential characteristics for success. ASCD.

Dewey, J. (1910). How we think. Boston: D. C. Heath.

Dewey, J. (1920). Reconstruction in philosophy. New York: Henry Holt.

Dewey, J. (1938). *Education and experience.* New York: Macmillan.

Dewey, J. & Small, A. W. (1897). *My pedagogic creed* (No. 25). New York: E. L. Kellogg & Company.

Dolmans, D. H., De Grave, W., Wolfhagen, I. H. & Van Der Vleuten, C. P. (2005). Problem-based learning: Future challenges for educational practice and research. *Medical Education, 39*(7):732–741. doi: 10.1111/j.1365-2929.2005.02205.x.

Eisberg, A. (2018, March 28). PBL vs product-based learning. *PBL Works; Buck Institute for Education*. https://www.pblworks.org/blog/pbl-vs-product-based-learning

Foster, P. (1994). Historical problems in industrial arts and technology education. American Vocational Association. https://files.eric.ed.gov/fulltext/ED383870.pdf

Hattie, J. (2012). *Visible learning for teachers: Maximizing impact on learning*. New York: Routledge.

International Technology and Engineering Educators Association (ITEEA). (2020). *Standards for technological and engineering literacy: The role of technology and engineering in STEM education. www.iteea.org/STEL.aspx*

Kimbell, R. A., Stables, K. Wheeler, A. D., Wozniak, A. V. & Kelly, A. V. (1991). The assessment of performance in design & technology. London UK: Schools Examinations and Assessment Council (SEAC).

Larmer, J., Mergendoller, J. & Boss, S. (2015). *Setting the standard for project based learning: A proven approach to rigorous classroom instruction*. Alexandria, VA: Association for Supervision and Curriculum Development.

Maley, D. (1969). The Maryland plan for industrial arts in the junior high school and the behavioral task analysis approach [microform] / Donald Maley. [Washington, D.C.] : Distributed by ERIC Clearinghouse https://eric.ed.gov/?id=ED034852

McDowell, M. (2017). *Rigorous PBL by design: Three shifts for developing confident and competent learners*. Thousand Oaks, CA: Corwin.

Mehta, J. & Fine, S. (2020). *In search of deeper learning: The quest to remake the American high school*. Cambridge, MA: Harvard University Press.

Moye, J. J.; Dugger, W. E., Jr. & Starkweather, K. N. (2014, September). "Learning by doing" research: Introduction. *Technology and Engineering Teacher,* 74(1), 24-27.

Scherer, R. (2022, June 8). What is PBL?. *hth unboxed, 22*. https://hthunboxed.org/what-is-pbl/

Schroeder, C.M., Scott, T.P., Tolson, H., Huang, T., & Lee, Y. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching, 44*(10), 1436-1460.

Strobel, J., Wang, J., Weber, N. R., & Dyehouse, M. (2013). The role of authenticity in design-based learning environments: The case of engineering education. *Computers & Education, 64,* 143-152.

Turns, J. A., Sattler, B., Yasuhara, K., Borgford-Parnell, J. L., & Atman, C. J. (2014, June). Integrating reflection into engineering education. In *2014 ASEE Annual Conference & Exposition (pp. 24-776).*

Williams, A. & Williams, P. J. (1997). Problem-based learning: An appropriate methodology for technology education. *Research in Science & Technology Education, 15*(1), 91-103.

Wolk, S. (2022, September 26). Clearing up misconceptions about project-based learning. Kappanonline.org. https://kappanonline.org/misconceptions-project-based-learning-wolk/