PLTW Biomedical Science, Computer Science and Engineering:

Evidence-based Learning Solutions for High School Students

Introduction

Project Lead The Way (PLTW) is the leading PreK-12 applied learning curriculum and teacher professional development provider with pathways in biomedical science, computer science, and engineering. PLTW provides engaging, high-quality activities and projects that encourage students to use what they learn in the classroom to solve real-world problems. Developed by instructional designers, teachers, and industry experts, the PLTW curriculum enables students to gain mastery of important science standards and concepts, while building transportable skills that include problem-solving, critical and creative thinking, collaboration, communication, and ethical reasoning and mindset.

PLTW's teaching and learning approach uses activities to build content knowledge, and incorporates projects and open-ended problems to achieve understanding, develop meaning, and reinforce transportable skills.

Problem Statement

Now more than ever, schools are facing intense pressure to maximize every instructional minute to ensure students master essential content standards while developing transportable skills. Educational leaders recognize the added value of new or existing programs reinforcing current priorities and cross-pollinating research-based strategies across district-wide initiatives. Additionally, high school educators recognize that they must engage students in learning that allows for exploration of college and career pathways and addresses their social and emotional developmental needs.

Background

Problem- and Project-based Learning

We know that problem-based (PBL) and project-based (PjBL) learning approaches positively impact student achievement, increase intrinsic motivation and participation, and develop critical thinking skills (Allen, 2000; Auler, 2020; Bowen & Peterson, 2019; Cole & Weinland, 2013; Jerzembek et al., 2013; Lee & Blanchard, 2019; Lucas Education Research, 2021; Miller & Krajcik, 2019; Nowrouziaan & Farewell, 2013; Sungar & Tekkaya, 2006; Wilder, 2015; Wirkala & Kuhn, 2011). Furthermore, we know that "social, emotional, and academic development is an essential part of PreK-12 education that can transform schools into places that foster academic excellence, collaboration and communication, creativity and innovation, empathy and respect, civic engagement, and other skills and dispositions needed for success in the 21st Century" (Jones, Kahn, & the Aspen Institute, 2017, p. 9). Research also demonstrates "a link between student perceptions of PBL and ultimate student interest in future STEM careers'' (Laforce, Nobel, & Blackwell, 2017, p. 17).

PBL and PjBL overlap with learning experiences that "launch from an open-ended question, scenario, or challenge" that focuses on engaging students in solving open-ended, real-world situated problems while building content understanding and critical thinking and collaboration skills (Krauss & Boss, 2013, p. 10). With this approach, "students make sense of why content is useful and how it might be applied" (Lucas Education Research, 2021, p. 1). PBL has been described as "an instructional method in which students

learn through facilitated problem solving" (Hmelo-Silver, 2004, p. 235). The emphasis is "not on the outcome but on the process" (Cerezo, 2004, p. 1). PBjL is a "model that organizes learning around projects" that stem from challenging questions and involve students in problem-solving, investigation, designing, making decisions, and result in products or presentations (Thomas, 2000, p. 1).

PLTW's APB Approach

Grounded in the evidence-based research on PBL and PjBL, the PLTW APB (activity-, project-, problem-based) instructional approach develops conceptual understanding as students are "actively gathering information, making observations, formulating questions, and then creating new ideas or solutions to answer their own inquiries'' (Krauss & Boss, 2013, p. 31). Research indicates that coupling a problem- or project-based approach with STEM learning has a positive impact on student learning, critical thinking skills, and social-emotional learning (Alemdar, et al., 2018; Cerezo, 2004; Harris, et al., 2015; Krajcik et al., 2021). "A well-designed project causes students to stretch their intellectual muscles in ways that traditional learning activities may not" (Boss & Krauss, 2018, p. 74). Embedded social-emotional learning builds student confidence, increases engagement in learning, improves grades, and reduces behavior issues (Greenberg et al., 2017). APB learning allows students to develop social, emotional, and cognitive skills through authentic problem-solving.

PLTW has transformed traditional, teacher-led classrooms into collaborative spaces where students solve problems, think creatively, and apply their learning in real-world contexts. The APB approach helps students become active and engaged learners by creating student-centered learning experiences in which teachers act as facilitators, rather than lecturers. In this environment, students learn by doing and begin to lead their own discovery as they work through hands-on activities, projects, and problems that become increasingly open-ended as they progress through the curriculum and become more challenging as they advance through a course. As students work toward problem solutions, teachers guide students through scaffolded learning that develops key concepts and processes related to the core course content (Allen et al., 2011). Students "develop flexible knowledge, effective problem-solving skills, self-directed learning skills, effective collaboration skills, and intrinsic motivation" (Hmelo-Silver, 2004, p. 235). Critical thinking is embedded in the process as students investigate phenomena and make sense of the world around them.

- **Activities** engage students to develop knowledge and skills they'll use to navigate navigate projects and real-world problems. They are structured, hands-on learning experiences that engage students in exploring phenomena as they seek to make sense of the world around them.

- **Projects** encourage meaning-making as students draw on their learning and background understandings to investigate concepts or skills.

- **Problems** are open-ended with no clear or best solution or solution path intended. They challenge students to apply their learning in novel situations that reflect real-world challenges placing students in the role of scientists and engineers.

Hmelo-Silver (2004) concluded, "Problem-based learning is well-suited to helping students become active learners because it situates learning in real-world problems and makes students responsible for their learning" (p. 236). Students "gain important knowledge, skills, and dispositions…" as they work collaboratively to investigate open- ended questions (Krauss & Boss, 2013, p. 5). Providing a scaffold for students as they actively learn is a critical component of PBL (Allen, et al., 2011). The APB approach builds problem-solving and process thinking, technical expertise, collaborative practices, and communication skills as students develop conceptual understanding.

APB learning also fosters a strong sense of self-efficacy as students may set higher goals for themselves, demonstrate firmer commitment to their goals, consider more career options as possibilities, and see an impact on academic achievement (Bandura, 1993, 1997; Parajes, 2003). We know that "in order for students to meet high expectations for learning and development, the heavy lifting must be done by the student, but schools and teachers need to provide relevant, rigorous, grade-level, opportunities and support" (Aspen Institute, 2019, p. 6). Learning experiences are designed to build students' capacity for responsible decision-making, self- and social-awareness, and relationship skills (Greenberg et al, 2017; Taylor et al., 2017; Wilder, 2015). Students who learn this way are more likely to "share the same goal, feel

supported, value the learning, become more competent, and more likely to persevere when facing learning challenges" (Lee & Blanchard, 2019, p. 1).

Essential features of the APB approach include student-centered learning, the teacher as facilitator, collaborative learning experiences, application of learning to solve problems, meaningful feedback and assessment, and a scaffold of learning experiences across the APBs. PLTW believes in this approach because it guides students toward owning their own learning, provides scaffolding, and prepares students to tackle challenges. Creating a problem scenario that is real-world and relevant to the learner's world, "effectively eliminate[s] the students' often posed question, 'Why do we need to know this?'" (Lambros, 2002, p. viii). PLTW's APB approach leverages research to create a high-impact, high-interest experience for students and teachers. Students thrive when given the opportunity to demonstrate evidence of their learning as they solve open-ended, real-world problems.

Solution

Why PLTW?
High school students need opportunities to develop deep learning, which encompasses content mastery, critical thinking, problem solving, collaboration, effective communication, self- directed learning, and academic mindsets (Hewlett Foundation, 2013). They need to engage in learning experiences that allow them to build and apply ethical reasoning. Additionally, they need learning experiences that allow for career exploration, bring awareness to the diversity in opportunities and breadth of careers, and provide students the opportunity to plan their educational path and career journey. They need an environment that fosters and empowers them with relevant content and opportunities to explore their interests. PLTW high school courses in biomedical science, computer science, and engineering offer deep learning through evidence-based, interdisciplinary experiences that are scaffolded for success by employing the hands-on APB instructional approach.

As students navigate the open-ended problems, they are immersed in exploration of phenomena that leads to understanding technical skills and STEM concepts. Whether ultimately seeking careers in health care, engineering, or computer science fields, students in PLTW courses practice how to think creatively and critically and apply ethical reasoning. They learn to to innovate and gain practical experience tackling real-world challenges that professionals face in the field, using both experimental design and the design process. The impact on student learning is why PLTW Biomedical Science, Computer Science, and Engineering pathways have become the cornerstone of transforming teaching and learning for thousands of educators and millions of students across the U.S.

In addition to providing "best in class" STEM education, PLTW's approach to learning strengthens schools' and districts' commitment to a project- and problem-based instructional model to maximize engagement and contextualize crucial science, math, and literacy objectives. Project- and problem-based learning encourages students to develop mastery of academic and technical learning using hands-on lessons. The successful pedagogical approach builds the capacity of students to "understand the information more clearly, remember the information more accurately, perform in assessments more competently, and transfer the knowledge and skills to a new context" (Homes & Hwang, 2016, p. 449). Engaging students in solving real-world problems "not only develops knowledge in a more complex way, but helps students develop 21st century skills such as emotional intelligence, communication skills, and complex thinking" (Auler, 2020, p. 33).

Biomedical Science, Computer Science, and Engineering Pathways
We know that PLTW participation has a positive impact on students' interest in pursuing additional STEM coursework and postsecondary education (Pendola, 2013; Overschelde, 2013; Rethwisch, 2014; Voicheck, 2011). Using PLTW's unique APB instructional approach, students explore relevant standards while applying math and literacy skills to solve real-world problems. Students are empowered to discover and explore their interests, imagine and design solutions to real-world challenges, apply ethical reasoning, and become independent, confident problem solvers. PLTW offers multiple courses across three pathways to meet the learning needs and interests of high school students:

- **Biomedical Science courses** Principles of Biomedical Science, Human Body Systems, Medical

Interventions, and Biomedical Innovation

- **Computer Science courses** Computer Science Essentials, Computer Science Principles, Computer Science A, and Cybersecurity
- **Engineering courses** Engineering Essentials, Introduction to Engineering Design, Principles of Engineering, Aerospace Engineering, Civil Engineering and Architecture, Computer Integrated Manufacturing, Computer Science Principles, Digital Electronics, Environmental Sustainability, and Engineering Design and Development

When PLTW students apply their learning in novel situations, a deeper level of understanding is demonstrated that goes beyond just memorizing facts or procedures (Miller & Krajcik, 2019). The PLTW high school courses build students' capacity for responsible decision-making, self- and social-awareness, and relationship skills (Greenberg et al, 2017; Taylor et al., 2017). And as students engage in PLTW's activities in biomedical science, computer science, and engineering, they see a range of paths and possibilities they can look forward to beyond high school. The interdisciplinary approach allows them to make connections among disciplines as they apply cognitive, technical, and transportable skills to solve real-world problems and challenges.

PLTW learning experiences are anchored in relevant content standards and focused on big ideas and foundational skills critical to future learning. All PLTW pathways address national bodies of standards that include:

- **PLTW Biomedical Science:** National Health Science Education Standards, Next Generation Science Standards, Common Core State Standards for Mathematics and English Language Arts
- **PLTW Computer Science:** Computer Science Teachers Association K-12 Computer Science Standards (CSTA), Standards for Technological and Engineering Literacy, National Cybersecurity Workforce Framework (NICE), College Board Frameworks
- **PLTW Engineering:** Standards for Technological and engineering Literacy (STEL), Next Generation Science Standards, Common Core State Standards for Mathematics and English Language Arts

Building Teacher Capacity

We know that teachers provide the necessary conditions for student success, and that ongoing participation in robust professional learning experiences prepares teachers to create these conditions in their classrooms. APB learning experiences call for teachers to implement new skills and tools. "For secondary teachers trained in one academic discipline, the challenge to integrate subject areas and build understanding of concepts outside their areas of expertise arise" (Geesa, Stith & Teague, 2021, p. 14). **PLTW Professional Development** empowers teachers to engage students in real-world and transformative APB learning experiences, inspiring them to impact the world with their learning. Teachers build their capacity with content and pedagogy and increase their ability to integrate math and science into the activities, projects, and problems (Nathan et al., 2011). PLTW Professional Development is grounded in research that indicates effective professional development "leads to improvements in teacher knowledge or practice, or in student learning outcomes (Jaquith et al., 2011, p. 2). Embedding "a focus on curriculum and shared instructional challenges; collective participation; opportunities for active learning; sustained duration; and coherence with student achievement goals and other policies," PLTW Professional Development transforms teaching and learning (National Institute for Excellence in Teaching, 2012, p. 1).

Conclusion

The impact of the APB instructional approach extends far beyond a single classroom. In many cases, it has reinvigorated the learning experience across entire schools, as teachers are intentionally finding more opportunities to build student interest and engagement. This means more student-to-student discussion and discourse and less teacher-centered instruction, allowing for creativity, collaboration, and problem-solving in all subject areas. The approach to learning "enables students to master their learning strategies and obtain greater understanding of phenomena" (Reid-Griffin et al., 2020, p. 6). "Students need to see purpose in their learning and experience of school" (Aspen Institute, 2019, p. 6).

Research confirms that PLTW offers a program that prepares students for success cognitively, socially, and emotionally. "As education works to reconnect student learning to something more than standardized testing, project-based learning (PBL) has become a popular way to increase student engagement while providing more authentic applications of student knowledge" (Bowen & Peterson, 2019, p. 1). The APB instructional approach and the integrated curriculum design is a proven and effective way to deliver meaningful engagement in learning to complete the cradle-to-college and career pipeline for students. Students who participate in PLTW courses build strong conceptual and technical understanding in STEM areas, as well as developing transportable skills that include critical thinking, collaboration, communication, problem-solving strategies, and ethical reasoning and mindset to benefit them in learning and in life.

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