Project Lead The Way [PLTW] Engineering Essentials

PEIMS Code: N1303760

Abbreviation: ENGESS

Grade Level(s): 9-12

Award of Credit: 1.0

Approved Innovative Course

- Districts must have local board approval to implement innovative courses.
- In accordance with Texas Administrative Code (TAC) §74.27, school districts must provide instruction in all essential knowledge and skills identified in this innovative course.
- Innovative courses may only satisfy elective credit toward graduation requirements.
- Please refer to TAC §74.13 for guidance on endorsements.

Course Description:

Engineering Essentials (EES) is for grade 9-12 students. Students explore the work of engineers and their role in the design and development of solutions to real-world problems. Students are introduced to engineering concepts applicable across multiple engineering disciplines. They are empowered to build technical skills using a variety of engineering tools. Students learn and apply the engineering design process to develop mechanical, electronic, process, and logistical solutions to relevant problems across a variety of industry sectors. Using PLTW's activity-, project-, problem-based (APB) instructional approach, students advance from completing structured activities to solving open-ended projects and problems that provide opportunities to develop planning and technical documentation skills and in-demand, transportable skills, such as problem solving, critical and creative thinking, collaboration, communication, and ethical reasoning. The course emphasizes statistical analysis and mathematical modeling – computational methods commonly used in engineering problem-solving.

Essential Knowledge and Skills:

(a) General Requirements. PLTW Engineering Essentials (EES)- This course is recommended for students in grades 9-12. There are no prerequisite courses required for enrollment in Engineering Essentials. This course provides 1.0 unit of credit.

(b) Introduction.

(1) Engineering Essentials (EES) is for grade 9-12 students. Students explore the work of engineers and their role in the design and development of solutions to real-world problems. Students are introduced to engineering concepts applicable across multiple engineering disciplines. They are empowered to build technical skills using a variety of engineering tools. Students learn and apply the engineering design process to develop mechanical, electronic, process, and logistical solutions to relevant problems across a variety of industry sectors, including health care, public service, and product development/manufacturing. Using PLTW's activity-, project-, problem-based (APB) instructional approach, students advance from completing structured activities to

solving open-ended projects and problems that provide opportunities to develop planning and technical documentation skills, and in-demand, transportable skills, such as problem solving, critical and creative thinking, collaboration, communication, and ethical reasoning. The course emphasizes statistical analysis and mathematical modeling – computational methods commonly used in engineering problem-solving.

(2) Students investigate engineering career fields and determine the technical literacy and career-specific knowledge and skills to support professional practice and incorporate computational thinking, modeling, systems thinking, professional practices and communication, project management, collaboration and professionalism and ethics, as critical parts of a problem-solving process that supports the ability to interpret complex, open-ended problems across all disciplines.

(3) Statements that contain the word "including" reference content that must be mastered, while those containing the phrase "such as" are intended as possible illustrative examples.

(c) Knowledge and Skills.

(1) Engineering Mindset - The student demonstrates independent thinking and self-direction in pursuit of accomplishing a goal, demonstrates creativity, flexibility, and adaptability to change, perseveres to solve a problem or achieve a goal, and makes judgments and decisions based on evidence. The student is expected to:

(A) explain the limitations of one’s knowledge and skills in pursuit of accomplishing a goal;

(B) plan and use time effectively in pursuit of accomplishing a goal without direct oversight;

(C) make and execute a plan to gain additional knowledge and learning to accomplish a goal;

(D) ask probing questions to expand and build upon an idea and explore personal curiosities throughout a creative process;

(E) explain the importance of adjusting to changes that impact work, such as adapting to varied roles, job responsibilities, and schedules;

(F) seek out and use feedback to improve work and positively influence one’s personal and professional development;

(G) describe how past experiences can be utilized to inform future progress;

(H) identify relevant data in credible sources, such as literature, databases, and policy documents;

(I) collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions;

(J) evaluate point of view, reasoning, and use of evidence and rhetoric in oral or written communication, and identify deficiencies, limitations, and biases; and

(K) draw valid conclusions based on supporting evidence while acknowledging the limitations, opposing views, and biases.

(2) Design Process – The student formulates a plan to solve an engineering problem or explore an opportunity and applies an iterative design process to creatively address a need or solve a problem. The student is expected to:

(A) describe major steps of a design process and identify typical tasks involved in each step;

(B) identify and explain the need for an engineering solution to a problem through the application of mathematics, science, and technology;

(C) transform an ill-formed problem into a meaningful, well-defined problem using relevant information;

(D) identify and define visual, functional, and structural design requirements and realistic constraints against which solution alternatives can be evaluated and optimized;

(E) identify potential constraints that that may impact the broader success of a design solution, such as economic, environmental, social, political, legal and regulatory, ethical, health and safety, manufacturability, technical feasibility, and sustainability considerations;

(F) apply effective techniques and appropriate guidelines to generate multiple creative ideas and potential solutions to a problem;

(G) implement a plan to compare competing solution ideas and justify the selection of a solution path with respect to design requirements and constraints;

(H) develop a potential solution that meets all constraints and complies with all design criteria;

(I) develop and implement a plan to test and evaluate the design solution to verify that it meets all constraints and complies with all design criteria; and

(J) identify design flaws of and potential enhancements to a proposed design solution and then iterate steps of the design process, as necessary, to improve and optimize a solution.

(3) Experimental Design – The student designs an experimental protocol that includes a testable hypothesis to investigate a phenomenon and gain knowledge and performs an experiment to collect and analyze data to draw conclusions and accurately represent experimental data using appropriate visualization techniques or statistical models. The student is expected to:

(A) develop a testable hypothesis, based on previously obtained knowledge or research and supported by scientific evidence, to address a problem or answer a question;

(B) identify and explain the purpose and importance of experimental controls;

(C) identify and distinguish between independent and dependent variables;

(D) identify best strategies and appropriate tools for data collection, documentation, and analysis;

(E) summarize the objective and relevancy of an experiment;

(F) read and accurately follow established protocols and instructions;

(G) identify possible sources of errors, if they exist, redesign, and repeat the experiment when appropriate;

(H) identify strengths, weaknesses, limitations, and next steps of a study;

(I) represent experimental data graphically for a single count or measurement with charts or plots on the real number line, such as box plots;

(J) use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range) of two or more different data sets and interpret differences in shape, center, and spread in the context of the data sets;

(K) organize and display experimental data to effectively communicate information; and

(L) draw conclusions related to a hypothesis and support those conclusions using experimental data.

(4) Physical Properties – The student measures quantities related to an electrical circuit, uses physical properties to inform decisions, such as designing an object or structure to satisfy physical constraints or minimize cost, and calculates quantities associated with an electrical circuit. The student is expected to:

(A) accurately measure current, voltage, and resistance within a circuit;

(B) solve real-world and hypothetical mathematical problems involving area and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, right prisms, cylinders, cones and spheres;

(C) solve real-world and hypothetical mathematical problems involving volume of a geometric form;

(D) solve real-world and hypothetical mathematical problems involving density of a component;

(E) calculate circuit resistance, current, and voltage within a circuit; and

(F) explain how energy is converted between electrical energy and other forms of energy.

(5) Computational Thinking – The student applies problem decomposition skills, uses algorithms, formulates solutions that use automation and programming, and applies abstraction to generalize problems and solutions. The student is expected to:

(A) separate a complex process into multiple subprocesses that can be implemented in an organized way to complete the larger process;

(B) follow a verbal or written algorithm accurately to accomplish a task or bring about a desired outcome;

(C) identify patterns in an algorithm to modularize or iterate repetitive tasks;

(D) write a set of ordered instructions with or without a computer involving multiple discrete steps to accomplish a complex task or achieve a desired result;

(E) implement and analyze algorithms using conditional logic;

(F) create, interpret, and modify a program to manage inputs and outputs of a microcontroller;

(G) use web or mobile development to contribute to the solution of a problem;

(H) create programs by writing and testing code in a modular, incremental approach;

(I) improve readability of code by creating or improving documentation, using self-documenting variable and function names, and using comments in a program;

(J) explore and use documentation and public information to extend one's own knowledge of a programming language or to achieve a computational approach to solving a problem;

(K) populate a spreadsheet application with data and organize the data to be useful in accomplishing a specific goal;

(L) use the functions and tools within a spreadsheet application to manipulate, analyze, and present data in a useful way, including graphs, regression analyses, and descriptive statistical analyses;

(M) create or convert electronically stored data or computer models to appropriate formats that can be utilized by other tools or applications, such as rapid prototyping equipment, Global Information Systems, and spreadsheet applications;

(N) identify the changes that are attributed to an abstraction and what details have been hidden or removed; and

(O) distinguish analog and digital characteristics of physical systems and how they represent abstractions.

(6) Modeling – The student develops models and simulations, uses spatial visualization, creates technical drawings, creates and interprets a computer model or simulation of simple objects, assemblies, or systems, and creates and interprets geospatial representations. The student is expected to:

(A) explain how models use abstraction to represent a simplified version of a complex phenomenon and why there is no guarantee that the model accurately represents the real object or phenomenon;

(B) list differences, potential or real, between model behavior and the behavior of the real object, system, or process that it represents and identify limitations of the model, including specific characteristics being studied, accuracy, precision, and range of conditions;

(C) develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose;

(D) use a mathematical model, such as algorithms, equations, graphs, Boolean expressions, or truth tables, to represent data, describe relationships, describe processes, and to make predictions in the context of the problem;

(E) combine or group solid geometric primitives to create more complex, three-dimensional objects using the additive solid modeling method;

(F) combine or group solid geometric primitives to remove a portion of one or more objects to create a more complex, three-dimensional object using the subtractive solid modeling method;

(G) create precise three-dimensional models using alignment, grid, and parametric modeling features within a computer-aided design application;

(H) build a physical representation of an object, system, or environment, including building solid objects, electrical circuits, mechanical devices, and complex systems, according to technical drawings;

(I) sketch by hand isometric views of a simple object or part at a given scale using the actual object, a detailed verbal description of the object, pictorial view of the object, or set of orthographic projections;

(J) build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors of a design idea or real object, which can include the appropriate application of geometric constraints, as well as modeling other physical properties, such as density, color, texture;

(K) simulate a circuit using appropriate technology;

(L) identify applications of geographic information systems for common purposes to acquire, analyze, report, and present information from a spatial perspective;

(M) differentiate between spatial and attribute information on a map;

(N) explain what geocoding is and how it works and use resulting location information to find objects, people, places, and environments;

(O) use geographical information systems technology to demonstrate spatial thinking and problem-solving;

(P) use geographical information systems technology to identify and analyze spatial patterns within maps and data; and

(Q) use geographical information systems technology to model features in a geographic area and show the locations and attributes of natural and man-made features or events using appropriately selected maps or layers.

(7) Systems Thinking – The student applies systems and subsystems thinking to evaluate the sustainability of an engineering problem and its solution. The student is expected to:

(A) describe a system in terms of its components or subsystems and their interactions, such as describe the components of an electronic circuit;

(B) describe how an electronic circuit provides power to a larger system to produce mechanical motion;

(C) describe the subsystems of a building, including power system, communication system, lighting system, ventilation system, water system, sewer system, safety system, social system, transportation system, structural system;

(D) describe how the water system and sewer system interact in one's home;

(E) predict what the effect of making a change to a component of a system will have on the system as a whole;

(F) predict the local and global risks and impacts of an engineering decision or solution on society, the economy, and the environment, including some that were not anticipated; and

(G) define sustainability and identify principles that help guide development of sustainable solutions.

(8) Professional Practices and Communication – The student demonstrates awareness of the education and skills required for professional practice in an engineering field, analyzes the role of engineering professionals in society, and develops a professional understanding of the need for multidisciplinary solutions to increasingly complex and persistent global challenges. The student is expected to:

(A) define engineering as the creation of solutions, such as new and improved products, technologies, systems and processes, to meet the needs of people and society;

(B) identify the technical and nontechnical skills common to all engineering disciplines that are gained from specialized and intense education, training, and experience, including problem solving, the design process, data processing and interpretation, handling uncertainty, systems thinking, and modeling;

(C) describe historically traditional disciplines of engineering, including civil, electrical, and mechanical as well as the discipline of industrial engineering;

(D) identify engineering discipline expertise that is critical to the solution of a specific problem;

(E) identify and describe contemporary engineering issues of local, global, and cultural significance; and

(F) describe the interdisciplinary nature of modern engineering and explain why an interdisciplinary approach to engineering problem-solving can result in better, more sustainable solutions.

(9) Project Management – The student applies project management tools when designing and developing a solution to successfully deliver a product using available resources. The student is expected to:

(A) explain the process of project management and the importance of phases such as initiating, planning, executing, and closing;

(B) define the project deliverables and constraints, such as scope, time, cost, quality, resources, and risk;

(C) develop a project schedule with the critical path identified, allocate tasks among team members, and track progress for successful completion of the project; and

(D) select and use collaborative tools, such as cloud-based tools, document sharing, and video and text functions, to successfully complete a project.

(10) Professionalism and Ethics – the student applies personal and professional ethical standards as they relate to the habits and characteristics of an engineering professional and considers the impact of potential engineering solutions on future generations to inform the development of sustainable solutions. The student is expected to:

(A) explain why engineers have a responsibility to serve the public interest, their clients, and the profession with a high degree of honesty, integrity, and accountability;

(B) describe the local, national, and international perspectives and ideas of others;

(C) explain why different engineering solutions can have significantly different impacts on individuals, society, and the natural world;

(D) evaluate a solution to a complex real-world problem and identify the need for trade-offs to address a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts;

(E) describe an example of sustainable development using an ethical decision-making process, including using natural resources effectively and efficiently and considering the safety of those affected by a product and potential effects on individual and public health; and

(F) describe the importance of respect and empathy for teammates, mentors, employers, teachers, clients, other professional contacts, and those impacted by engineering decisions.

(11) Collaboration – the student facilitates an effective team environment to promote successful goal attainment, contributes individually to overall collaborative efforts, and analyzes and evaluates the work of others to provide helpful feedback. The student is expected to:

(A) develop and follow team norms;

(B) monitor, solicit, negotiate, and balance diverse views and beliefs to reach shared understanding, common ground, and workable solutions;

(C) identify basic resolution strategies and employ those strategies as necessary and appropriate;

(D) develop ideas and create products through positive interdependence among all teammates;

(E) describe one's individual role and expectations of performance within a team, including communication protocol and rules of engagement per team norms;

(F) support other team members, prompting and offering assistance, if needed, to meet team goals;

(G) present all work being done individually in a timely manner to the team to gather feedback, inform revision, and gain consensus;

(H) self-evaluate personal contributions and collaboration effectiveness within a team;

(I) describe the purpose and positive outcomes of a peer review process; and

(J) provide effective feedback to peers.

(12) Communication – the student communicates effectively with an audience based on audience characteristics. The student is expected to:

(A) document engineering or scientific work in an organized notebook so that someone unfamiliar with the work can follow and understand the process;

(B) use tables, charts, and graphs in making arguments and claims in oral, written, and visual presentations;

(C) initiate and participate in a range of open and effective interactions, such as one-on-one, in groups, and teacher-led, with diverse participants and across cultures, building on others' ideas and expressing one's own clearly and persuasively;

(D) produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience;

(E) present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and ensure that the organization, development, substance, and style are appropriate to purpose, audience, and task;

(F) create presentations to enhance understanding of findings using digital media, such as textual, graphical, audio, visual, and interactive elements; and

(G) explain the process of active listening.

Recommended Resources and Materials:

The most current version of the PLTW curriculum must be used for instruction. Teacher and student resources are developed by PLTW and can be accessed by trained teachers, authorized district personnel, and rostered students through the PLTW Instructional Management System. Access to PLTW resources is through myPLTW.org after the appropriate training or authorization has been completed.

Materials:

In addition to the instructional equipment and materials required for the specific activities, projects, and problems, each student in a class must have access to a computer that meets PLTW's specifications and is furnished with the appropriate software for the course. These requirements are listed at:

https://www.pltw.org/get-involved/register-pltw/program-support/equipment-and-supplies

Resources:

- TinkerCAD. Autodesk. Online 3D Modeling Program. 2023.
- Environmental Systems Research Institute. ArcGIS Online. ESRI. 2023. https://www.arcgis.com/index.html
- Google Earth Engine. 2023. https://earthengine.google.com/timelapse/
- 2017 ASCE Infrastructure Report Card. 2017. https://www.infrastructurereportcard.org/solutions/gamechangers/
- Sustainable Development Goals. SDG Data Alliance . 2022. https://www.sdg.org/
- Kurup, Deepika. 2016. "A Young Scientist's Quest for Clean Water." Filmed 2016 in TEDWomen. TED video, 7:51, https://www.ted.com/talks/deepika_kurup_a_young_scientist_s_quest_for_clean_water?language=en
- Wujec, Tom. 2015. "Tom Wujec: Got a wicked problem? First, tell me how you make toast." Created February 2015. TED video, 9:05, https://www.youtube.com/watch?v=_vS_b7cJn2A

Recommended Course Activities:

- Using their personal engineering perspective, students reflect individually and within a team on global engineering challenges, choose a challenge that they feel is the most important challenge facing their generation, and gather evidence to make a persuasive presentation to convince an audience of its importance.
- Students employ experimental design to inform development of a model that represents important aspects of a phenomenon and develop a protocol to test the function of a mechanical device compared to design criteria.
- Students use geographic information systems to investigate natural and man-made systems that have the potential to inform design decisions.
- Students practice brainstorming techniques as they address ethical considerations related to systems thinking.
- Students work with rapid prototyping equipment to design and create physical models.
- Students practice using 3D design software to represent parts and systems and learn how to constrain degrees of freedom to simulate realistic motion.
- Students use technology to measure voltage, current, and resistance, and experiment to determine a mathematical model to represent the relationship among those quantities in a circuit.
- Students investigate how circuits work, learn to represent circuits with truth tables and logic expressions, and build physical models using integrated chips.
- Students use a microcontroller to gather data from multiple sensors.
- Students collaboratively design an input device that can be used later in the design of an electromechanical device.
- Students design, build, and test a rudimentary electromechanical system to model more sophisticated robotic systems common in some forms of laparoscopic surgery to serve as a training platform for first-year biomechanical engineering students.
- Students document their work (i.e., drawings, sketches, notes) in their engineering design notebook.

- Students create maps and layers in a geographic information system.
- Students use project management tools, like a project schedule, to promote project efficiency.

Suggested methods for evaluating student outcomes:

PLTW offers End-of-Course assessments that measure subject-matter knowledge as well as the in-demand, transportable skills. Additional assessment examples include:

- Online Polls
- Whole Class Whiteboarding
- 5x5 Journal – students journal about the five most interesting ideas they discover during a lesson and explain five aspects of that idea that resonate with them.
- Misconception Check – teacher states a common idea or misconception about a topic. Students either agree or disagree with the misconception and explain their reasoning.
- KWHLAQ Chart - Students make a chart answering the questions:
  K - What do I know?
  W - What do I want to know?
  H- How will I find out?
  L - What have I learned?
  A - What action will I take?
  Q - What new questions do I have?
- Rubrics
- Student Presentations
- Graphic Organizers
- Engineering Design Notebook
- PLTW End of Course Exam

Teacher qualifications:

- Legacy Master Science Teacher.
- Mathematics/Physical Science/Engineering: Grades 6-12.
- Mathematics/Physical Science/Engineering: Grades 8-12.
- Physical Science: Grades 6-12.
- Physical Science: Grades 8-12.
- Physics/Mathematics: Grades 7-12.
- Physics/Mathematics: Grades 8-12.
- Science: Grades 7-12.
- Science: Grades 8-12.
- Science, Technology, Engineering, and Mathematics: Grades 6-12.
- Secondary Industrial Arts (Grades 6-12).
- Secondary Industrial Technology (Grades 6-12).
- Secondary Physics (Grades 6-12).
- Secondary Science (Grades 6-12).
- Secondary Science, Composite (Grades 6-12).
- Technology Education: Grades 6-12.
- Legacy Master Mathematics Teacher.
- Mathematics: Grades 7-12.
- Mathematics: Grades 8-12.
- Secondary Mathematics: Grades 6-12

- Secondary Physical Science (Grades 6-12)
- Technology Applications: Grades EC-12
- Technology Applications: Grades 8-12
- Trade and Industrial Education: Grades 6-12. This assignment requires appropriate work approval.
- Trade and Industrial Education: Grades 8-12. This assignment requires appropriate work approval.
- Vocational Trades and Industry. This assignment requires appropriate work approval.

Additional information:

Successful completion of the PLTW Core Training for Engineering Essentials is required to offer this course.

PLTW Core Training:

PLTW's Core Training for Engineering Essentials requires approximately 90 hours of instruction led by PLTW approved Master Teachers (80 hours of class time plus 10 hours of prerequisite work). It is offered year-round with multiple options to allow teachers to select dates and pacing of their training session. Course mastery is demonstrated by the submission and approval of a course portfolio that meet's PLTW's requirements. After successful completion of Core Training, teachers receive access to the National PLTW Engineering Professional Learning Community, course-specific student and classroom instructional resources, and Ongoing Training resources through the PLTW Content Management System.

Current details, such as pricing and listings for all PLTW professional development, can be found at https://www.pltw.org/our-programs/professional-development/core-training. At the time of this application submission, the course cost is *$2,400.

Note: Currently, PLTW offers a training guarantee to schools. The PLTW Training Guarantee protects a district's investment in PLTW programs by guaranteeing if a teacher leaves within four years of earning a PLTW credential, PLTW will provide a grant in the amount of the training fee for the district to train a teacher in the same course, replace the credential(s), and support continued student learning.

* PLTW Professional Development Fees are subject to change annually. Changes are communicated via email from PLTW Communications and on the PLTW website at least 90 days prior to the effective date for the upcoming school year. There are no changes for the 2023-24 school year.

Districts may use these courses only with the approval of Project Lead The Way. All requirements of Project Lead The Way must be met.

Please contact Project Lead The Way directly for questions about these requirements:

Project Lead The Way

Solution Center

Toll Free: 877.335.PLTW (7589) solutioncenter@pltw.org