Orange Public Schools

Office of Curriculum & Instruction

2019-2020 Mathematics Curriculum Guide

Orange
Public Schools

PLTW Principles of Engineering

Curriculum Framework

September 9, 2019 – June 25, 2020

PLTW Framework - Overview

PLTW Frameworks are representations of the knowledge, skills, and understandings that empower students to thrive in an evolving world. The PLTW Frameworks define the scope of learning and instruction within the PLTW curricula. The framework structure is organized by four levels of understanding that build upon each other: Knowledge and Skills, Objectives, Domains, and Competencies.

The most fundamental level of learning is defined by course Knowledge and Skills statements. Each Knowledge and Skills statement reflects specifically what students will know and be able to do after they've had the opportunity to learn the course content. Students apply Knowledge and Skills to achieve learning Objectives, which are skills that directly relate to the workplace or applied academic settings. Objectives are organized by higher-level Domains.

Domains are areas of in-demand expertise that an employer in a specific field may seek; they are key understandings and long-term takeaways that go beyond factual knowledge into broader, conceptual comprehension.

At the highest level, Competencies are general characterizations of the transportable skills that benefit students in various professional and academic pursuits. As a whole, the PLTW Frameworks illustrate the deep and relevant learning opportunities students experience from PLTW courses and demonstrate how the courses prepare students for life, not just the next grade level.

To thrive in an evolving world, students need skills that will benefit them regardless of the career path they choose. PLTW Frameworks are organized to showcase alignment to in-demand, transportable skills. This alignment ensures that students learn skills that are increasingly important in the rapidly advancing, innovative workplace.

Competencies (C), Domains (D), Objectives (O), Knowledge and Skills (KS)

C1 Problem Solving and Process Thinking

Strategic and systematic design and inquiry processes guide the development of an effective solution to the problem.

D1 Engineering Mindset

Successful engineers typically exhibit specific personal and professional characteristics that lend themselves to the creative, collaborative, and solution-driven nature of the profession.

O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal.

KS1.1.1 Plan and use time in pursuit of accomplishing a goal without direct oversight.

O1.2 Demonstrate flexibility and adaptability to change.

KS1.2.1 Adapt to varied roles, job responsibilities, schedules, and contexts.

O1.3 Persevere to solve a problem or achieve a goal.

KS1.3.1 Describe why persistence is important when identifying a problem and/or pursuing solutions.

D2 Design Process

An engineering design process is an iterative, systematic approach to problem solving.

O2.1 Explain and justify an engineering design process.

KS2.1.1 Explain that there are many versions of a design process that describe essentially the same process.

KS2.1.2 Describe major steps of a design process and identify typical tasks involved in each step.

KS2.1.3 Identify the step in which an engineering task would fit in a design process.

- KS2.1.4 Document a design process in an engineering notebook according to best practices.

O2.2 Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions.

- KS2.2.1 Explain the role of research in the process of design.

O2.3 Synthesize an ill-formed problem into a meaningful, well-defined problem.

- KS2.3.1 Explain the importance of carefully and specifically defining a problem or opportunity, design criteria, and constraints, to develop successful design solutions.
- KS2.3.2 List potential constraints that may impact the success of a design solution. Examples include economic (cost), environmental, social, political, ethical, health and safety, manufacturability, technical feasibility, and sustainability.

O2.4 Generate multiple potential solution concepts.

- KS2.4.1 Represent concepts using a variety of visual tools, such as sketches, graphs, and charts, to communicate details of an idea.

O2.5 Develop models to represent design alternatives and generate data to inform decision making, test alternatives, and demonstrate solutions.

- KS2.5.1 Define various types of models that can be used to represent products, processes, or designs, such as physical prototypes, mathematical models, and virtual representations. Explain the purpose and appropriate use of each.

O2.6 Select a solution path from many options to successfully address a problem or opportunity.

- KS2.6.1 Explain that there are often multiple viable solutions and no obvious best solution. Trade-offs must be considered and evaluated consistently throughout an engineering design process.

O2.7 Plan and execute an investigation to collect valid quantitative data to serve as a basis for evidence and to inform decisions.

- KS2.7.1 Identify the data needed to answer a research question and the appropriate tools necessary to collect, record, analyze, and evaluate the data.

D3 Engineering Tools and Technology

The practice of engineering requires the application of mathematical principles and common engineering tools, techniques, and technologies.

O3.1 Using a variety of measuring devices, measure and report quantities accurately and to a precision appropriate for the purpose.

- KS3.1.1 Explain and differentiate between the accuracy and precision of a measurement or measuring device.
- KS3.1.2 Use dimensional analysis and unit conversions to transform data to consistent units or to units appropriate for a particular purpose or model.

O3.2 Use a spreadsheet application to help identify and/or solve a problem.

- KS3.2.1 Populate a spreadsheet application with data and organize the data to be useful in accomplishing a specific goal.
- KS3.2.2 Use the functions and tools within a spreadsheet application to manipulate, analyze, and present data in a useful way, including regression analyses and descriptive statistical analyses.

O3.3 Interpret and analyze data for a single count or measurement variable.

- KS3.3.1 Represent data for a single count or measurement with plots on the real number line, such as dot plots, histograms, and box plots.
- KS3.3.2 Use statistics appropriate to the shape of the data distribution to determine the center (median, mean) and spread (interquartile range, standard deviation) of a data set and/or compare data sets.

O3.4 Apply system thinking to consider how an engineering problem and its solution fit into broader systems.

KS3.4.1 List realistic considerations that constrain solutions within the broader system. Examples include economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.

O3.5 Construct physical objects using hand tools and shop tools.

KS3.5.1 Identify basic hand tools and shop tools and describe their function.

KS3.5.2 Demonstrate use of hand tools and shop tools.

O3.6 Apply computational thinking to generalize and solve a problem using a computer.

KS3.6.1 Interact with content-specific models and simulation to support learning and research.

KS3.6.2 Use modeling and simulation to represent and understand natural phenomena.

KS3.6.3 Develop an algorithm (step-by-step process) for solving a problem.

KS3.6.4 Identify, test, and implement possible solutions to a problem using a computer.

KS3.6.5 Automate a solution using algorithmic thinking.

C2 Technical Knowledge and Skills

Every career field requires technical literacy and career-specific knowledge and skills to support professional practice.

D4 Energy and Power

Energy and power are essential for the construction of a system its function.

O4.1 Identify appropriate applications and examples of each of the six simple machines.

KS4.1.1 Describe the attributes and components of each of the six simple machines.

KS4.1.2 Distinguish between the six simple machines.

O4.2 Measure forces and distances and calculate mechanical advantage, work, power, and efficiency in mechanical systems.

KS4.2.1 Identify the equations to solve for mechanical advantage, work, and power.

KS4.2.2 Measure forces and distances related to mechanisms.

KS4.2.3 Calculate mechanical advantage and drive ratios of mechanisms.

KS4.2.4 Identify the equations for work and power.

KS4.2.5 Calculate work and power in mechanical systems.

KS4.2.6 Determine efficiency in a mechanical system.

KS4.2.7 Identify the equation for calculating the efficiency of a system.

KS4.2.8 Calculate the mechanical power developed when lifting an object.

KS4.2.9 Design, build, and test a machine that efficiently channels mechanical energy when friction and limited input energy are significant constraints.

O4.3 Analyze parallel and series circuits resistance, current, and voltage using Ohm's law.

KS4.3.1 Identify the equations to calculate the resistance, current, and voltage of simple circuits.

KS4.3.2 Calculate electrical power developed in a circuit.

KS4.3.3 Calculate circuit resistance, current, and voltage using Ohm's law, including circuits with elements in series and/or parallel.

KS4.3.4 Compare and contrast the behavior of electrical circuits with parallel and series circuit designs.

O4.4 Identify appropriate applications of fuel and solar cells based on characteristics and function.

KS4.4.1 Explain that hydrogen fuel cells transform chemical energy stored in hydrogen gas to electrical energy and heat, converting hydrogen and oxygen into water.

KS4.4.2 Describe the use of reversible fuel cells as electrolyzers to store electrical energy for later use.

KS4.4.3 Describe the use of solar cells to convert light energy into electricity.

KS4.4.4 Test and apply the relationships among voltage, current, and resistance in series and parallel circuits that incorporate photovoltaic cells and hydrogen fuel cells.

KS4.4.5 Design a system to convert solar power to mechanical power using photovoltaic and fuel cells.

O4.5 Differentiate among conduction, convection, and radiation in the transfer of thermal energy.

KS4.5.1 Describe convection, conduction, and radiation as they relate to thermal energy transfer.

KS4.5.2 Design, construct, and test insulation materials for reducing thermal energy transfer.

KS4.5.3 Calculate the rate at which energy is transferred by conduction and radiation through materials having various R-values.

D5 Materials and Structures

The integrity of physical systems is dependent on their material properties and structural design.

O5.1 Draw free body diagrams of objects, identifying all forces acting on the object.

KS5.1.1 Differentiate between scalar and vector quantities.

KS5.1.2 Identify the magnitude, direction, and sense of a vector.

KS5.1.3 Explain how the forces acting on an object are in equilibrium.

KS5.1.4 Understand how Newton's Laws are applied to determine the forces acting on an object.

KS5.1.5 Create free body diagrams of objects, identifying all forces acting on the object.

KS5.1.6 Calculate the x and y components of a given vector.

O5.2 Calculate moment of inertia, beam deflection, and moments or torques.

KS5.2.1 Know that beam deflection is related to cross-sectional geometry and material properties.

KS5.2.2 Know that the moment of inertia is related to cross-sectional geometry.

KS5.2.3 Know that the modulus of elasticity defines the stiffness of an object related to material and chemical properties.

KS5.2.4 Mathematically locate the centroid of structural members.

KS5.2.5 Calculate the area moment of inertia of structural members.

KS5.2.6 Calculate the deflection of a center-loaded beam from the beam's geometry and material properties.

KS5.2.7 Calculate moments or torques given a force and a point of application relative to a specified axis.

O5.3 Analyze and solve for the external and internal forces on a truss.

KS5.3.1 Use equations of equilibrium to calculate unknown external forces on a truss.

KS5.3.2 Use the method of joints to calculate tension and compression forces in the members of a statically determinate truss.

KS5.3.3 Construct and destructively test a truss, and relate observations to calculated predictions.

O5.4 Conduct non-destructive tests for material properties.

KS5.4.1 Conduct non-destructive tests for material properties on selected common household products, including tests for continuity, ferrous metal, hardness, and flexure.

KS5.4.2 List material properties that are important to design, including mechanical, chemical, electrical, and magnetic properties.

O5.5 Describe how the formulas are applied to material loaded with a tensile force.

KS5.5.1 Describe how formulas for stress and strain are applied to a material loaded with a tensile force.

KS5.5.2 Describe how elastic and plastic deformation occurs in a material loaded with a tensile force.

KS5.5.3 Describe the modulus of elasticity.

O5.6 Use axial force experiments to create a stress-strain curve describing intrinsic material properties.

KS5.6.1 Measure axial force and elongation data of material samples and create stress-strain diagrams describing the intrinsic properties of the materials.

KS5.6.2 Calculate minimum or maximum design parameters to ensure a safe or reliable product using material strength properties.

KS5.6.3 Identify and calculate test sample material properties using a stress-strain curve.

D6 Control Systems

A control system is integrated into a larger system as a means to coordinate input and output devices.

O6.1 Distinguish between digital and analog data, and the inputs and outputs of a computational system.

KS6.1.1 Distinguish between digital and analog data, and between the inputs and outputs of a computational system.

O6.2 Describe differences and advantages of open- and closed-loop systems.

KS6.2.1 Distinguish between open- and closed-loop systems based on whether decisions are made using time delays or sensor feedback.

KS6.2.2 Identify the relative advantage of an open-loop or closed-loop control system for a given technological problem.

O6.3 Create a flowchart, pseudocode, and computer program to implement an algorithm.

KS6.3.1 Create a flowchart to describe an algorithm.

KS6.3.2 Create pseudocode to describe an algorithm.

KS6.3.3 Analyze and describe an algorithm represented as a flowchart or as programming code.

KS6.3.4 Create a computer program to implement an algorithm, including conditional statements and iterations.

O6.4 Predict the behavior of a control system and use a variety of methods for finding, identifying, and correcting bugs in a program.

KS6.4.1 Based on given needs and constraints, design and create a control system, including the inputs, computer program, and outputs.

KS6.4.2 Predict the behavior of a control system by examining the program it is going to execute.

KS6.4.3 Evaluate algebraic and logical expressions involving programming variables.

O6.5 Describe the advantages of hydraulic and pneumatic systems relative to each other.

KS6.5.1 Identify devices that use hydraulic and pneumatic power.

KS6.5.2 Distinguish between hydrodynamic and hydrostatic systems.

KS6.5.3 Identify the advantages of hydraulic and pneumatic systems relative to each other.

O6.6 Design a hydraulic and pneumatic device, calculating design parameters using Pascal's Law.

KS6.6.1 Design, create, and test a hydraulic device.

KS6.6.2 Design, create, and test a pneumatic device.

KS6.6.3 Calculate flow rate, flow velocity, power, and mechanical advantage in a fluid power system.

KS6.6.4 Identify and explain basic components and functions of fluid power devices.

KS6.6.5 Calculate values in a pneumatic system using the ideal gas laws.

KS6.6.6 Calculate design parameters in a fluid power system utilizing Pascal's Law.

KS6.6.7 Distinguish between pressure and absolute pressure.

KS6.6.8 Distinguish between temperature and absolute temperature.

D7 Statistics and Kinematics

Statistics can be applied to analyze testing results such as ballistic motion.

O7.1 Calculate probabilities of a variety of types of events.

KS7.1.1 Calculate the probability of making a set of observations in a series of trials where each trial has two distinct possible outcomes.

KS7.1.2 Calculate the theoretical probability that a simple event will occur.

O7.2 Apply AND, OR, and NOT logic as well as Bayes' Theorem to probability.

KS7.2.1 Apply AND, OR, and NOT logic to probability.

KS7.2.2 Apply Bayes' Theorem to calculate a probability in a manufacturing context.

O7.3 Apply statistical analysis to determine central tendency, mean, median, and mode.

KS7.3.1 Calculate the variation in a set of data, including range, standard deviation, and variance.

KS7.3.2 Name measures of central tendency and variation and describe their meaning.

KS7.3.3 Calculate the central tendency of a data set, including mean, median, and mode.

KS7.3.4 Produce a frequency distribution to describe experimental results and create a histogram to communicate these results.

KS7.3.5 Distinguish between sample statistics and population statistics and know appropriate applications of each.

O7.4 Describe free-fall motion.

KS7.4.1 Describe free-fall motion of a projectile as having constant velocity in the horizontal direction and uniformly accelerating motion in the vertical direction.

O7.5 Calculate distance, displacement, speed, velocity, and acceleration from data.

KS7.5.1 Calculate acceleration due to gravity given data from a free-fall trajectory.

KS7.5.2 Determine the angle needed to launch a projectile a specific range given the projectile's initial velocity.

KS7.5.3 Calculate distance, displacement, speed, velocity, and acceleration from data.

O7.6 Describe the location of a projectile in motion as a function of time.

KS7.6.1 Identify formulas related to motion of a projectile.

KS7.6.2 Calculate the location of a projectile at a specified time.

C3 Professional Practices and Communication

Professional practice is guided by professional ethics and standards and requires effective communication and collaboration.

D8 Career Awareness

Engineers use professional skills and knowledge to pursue opportunities and create sustainable solutions to improve and enhance the quality of life of individuals and society.

O8.1 Identify engineering disciplines and engineering expertise that are critical to the solution of a specific problem.

KS8.1.1 Describe the historically traditional disciplines of engineering, including civil, electrical, mechanical, and chemical.

KS8.1.2 Explain that engineering disciplines continue to evolve and emerge as new interdisciplinary fields or sub-disciplines to better meet the needs of society. Examples include: Aerospace Engineering, Biomedical Engineering, Environmental Engineering, Computer Engineering, Structural Engineering, and Water Resource Engineering.

D9 Professionalism and Ethics

Successful engineering professionals exhibit personal and professional characteristics and behaviors that involve considerations of the impact of their work on individuals, society, and the natural world.

O9.1 Assess an engineering ethical dilemma.

KS9.1.1 Explain that engineering solutions can have significantly different impacts on an individual, society, and the natural world.

D10 Collaboration

Demonstrate an ability to function on multidisciplinary teams.

O10.1 Facilitate an effective team environment to promote successful goal attainment.

KS10.1.1 Describe the various individual roles and interdependencies of a collaborative team.

KS10.1.2 Describe the importance of team norms and help develop those norms for a team.

KS10.1.3 Solicit, negotiate, and balance diverse views and beliefs to reach workable solutions.

KS10.1.4 Identify basic conflict resolution strategies and employ those strategies as necessary and appropriate.

O10.2 Contribute individually to overall collaborative efforts.

KS10.2.1 Describe one's individual role and expectations of performance within the team.

D11 Communication

Engineering practice requires effective communication with a variety of audiences using multiple modalities.

O11.1 Communicate effectively with an audience based on audience characteristics.

KS11.1.1 Adhere to established conventions of written, oral, and electronic communications (grammar, spelling, usage, and mechanics).

KS11.1.2 Follow acceptable formats for technical writing and professional presentations.

KS11.1.3 Properly cite references for all communication in an accepted format.

KS11.1.4 Clearly label tables and figures with units and explain the information presented in context.

KS11.1.5 Describe characteristics important to oral delivery of information (volume, tempo, eye contact, articulation, and energy). Vary these elements of delivery to convey and emphasize information and engage the audience.