3 - Mathematics, Statistics & Engineering Economics

Content Area: **Science**
Course(s): **Engineering Principles**
Time Period: **Sept-June**
Length: **30 Days**
Status: **Published**

Title Section

Department of Curriculum and Instruction

Belleville Public Schools

Curriculum Guide

Engineering Principals

3 - Mathematics, Statistics & Engineering Economics

Belleville Board of Education

102 Passaic Avenue

Belleville, NJ 07109

Prepared by: Joy Elaine Alfano, PhD

Dr. Richard Tomko, Ph.D., M.J., Superintendent of Schools

Ms. LucyAnn Demikoff, Director of Curriculum and Instruction K-12

Ms. Nicole Shanklin, Director of Elementary Education K-8, ESL Coordinator K-12

Mr. George Droste, Director of Secondary Education

Board Approved: September 21, 2020

Unit Overview

Engineering problems are mathematical models of physical situations with different forms that rely on a wide range of mathematical concepts. Therefore, good understanding of mathematical concepts is essential in the formulation and solution of many engineering problems. Statistical models are becoming common tools in the hands of practicing engineers to solve quality control and reliability issues and to preform failure analyses Civil engineers use statistical models to study the reliability of construction materials and structures and to design for flood control. Electrical engineers use statistical models for signal processing and for developing voice recognition software. Manufacturing engineers use statistics for quality control assurance of the products they produce. Mechanical engineers use statistics to study the failure of materials and machine parts. Economic factors also play important roles in engineering design decision making. If you design a product that is to expensive to manufacture, then it cannot be sold at a price that consumers will purchase and still be profitable to your company. There is a great importance to all of these mathematical, statistical, and economic concepts.

Enduring Understanding

1. Mathematics has its own symbols and terminology and it is important to understand what they mean and to use them properly when communicating with others.
2. Greek alphabetic characters are used in engineering to express angles, dimensions & physical variable
3. Linear models are the simplest form of equations used to describe a range of engineering situations

4. In a linear model, the value of the slope is always constant
5. Nonlinear models have variable slopes
6. When modeling an engineering problem using an exponential function, the rate of change of a dependent variable is much higher and the beginning and much lower at the end
7. The formulation of many engineering problems leads to a set of linear algebraic equations that are solved simultaneously which can be accomplished through matrix algebra
8. Calculus is divided into differential and integral calculation
9. Probability deals with that branch of science that attempts to predict the likelihood of an event. Each time you repeat an experiment, it is called a trial & the results are called outcomes. A random experiment is one that has random outcomes & randoms cannot be predicted exactly
10. Statistics deals with methods and techniques that can be used to draw conclusions about the characteristics of something with a large number of data points called a population using a smaller portion of the entire data
11. When organizing data we commonly identify high and low points and group data into equal intervals or ranges. Common organizations include frequency distributions, graphs, histogram, etc
12. A probability distribution shows the probability values for the occurrence of the outcomes of an experiment and a probability distribution that has a bell shaped curve is called a normal distribution - it is also important to know what the detailed bell shape of a normal distribution curve is determined by its mean and standard deviation values. An experiment with a small standard deviation will produce a tall narrow curve whereas a large standard deviation will result in a short wide curve - the area under any given normal distributions should always be equal to 1.
13. Economic plays an important role in engineering decision making.
14. Cash flow diagrams are visual aids that show the flow of costs and revenues over a period of time

Essential Questions

1. What are the basic characteristics of nonlinear models?
2. What is the difference between the slopes of a nonlinear model and a linear model?
3. What is meant by the real roots of a polynomial functions?
4. What are some of the important characteristics of exponential functions?
5. Explain the difference between the slopes of a nonlinear model and an exponential model?
6. Why do we define logarithmic functions and how are they defined?
7. How do we define the natural logarithm?
8. What is meant by the elements of a matrix?
9. What is meant by the size, transpose & determinant of a matrix?
10. What is the importance of differential and integral calculus in engineering?
11. What is meant by the rate of change and the integral sign representation?
12. What are the basic principles of probability and how do engineers use statistics?
13. Describe ways by which we can measure the dispersion of a reported data set?
14. What are good ways of defining dispersion and standard deviation, and probability distribution?
15. What is the normal distribution and what is significant about the normal distribution?
16. What is meant by cash flow diagram, simple interest, future worth of a present amount?
17. What are interest time factors, and how are they used in the analysis of engineering economic problems?
18. Based on engineering economic principals explain how you would best choose the best alternative from among many choices?

Exit Skills

- Use mathematical principles in design and engineering
- Apply statistics as an engineer of a product design
- Complete an economic evaluation of a product design

New Jersey Student Learning Standards (NJSLS-S)

HS-ETS1-1	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
HS-ETS1-4	Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
HS-PS3-1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
HS-PS3-2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative position of particles (objects).
HS-PS3-3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
HS-PS3-4	Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
HS-PS3-5	Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.
HS-PS4-1	Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Interdisciplinary Connections

MA.A-SSE.B	Write expressions in equivalent forms to solve problems
LA.WHST.11-12.1.A	Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

LA.WHST.11-12.1.B	Develop claim(s) and counterclaims using sound reasoning and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases.
LA.WHST.11-12.1.C	Use transitions (e.g., words, phrases, clauses) to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims.
LA.WHST.11-12.1.D	Establish and maintain a style and tone appropriate to the audience and purpose (e.g., formal and objective for academic writing) while attending to the norms and conventions of the discipline in which they are writing.
LA.WHST.11-12.1.E	Provide a concluding paragraph or section that supports the argument presented.
MA.A-REI.C.5	Prove that, given a system of two equations in two variables, replacing one equation by the sum of that equation and a multiple of the other produces a system with the same solutions.
MA.A-REI.C.6	Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables.
MA.A-REI.C.7	Solve a simple system consisting of a linear equation and a quadratic equation in two variables algebraically and graphically.

Learning Objectives

1. Explain each of the important mathematical symbols and Greek alphabetic characters
2. Explain linear equations, their characteristics and how they are used to describe engineering problems
3. Explain nonlinear equations, their characteristics and how they are used to describe engineering problems
4. Know about exponential and logarithmic functions, their important characteristics and how they are used to model engineering problems
5. State basic definitions and operations and why matrix algebra plays an important in solving engineering problems
6. Explain key concepts related to differential and integral calculus
7. explain what we mean by differential equations and give examples of boundary
8. Explain the basic ideas of probability and give examples
9. describe the ideas of statistics and give examples
10. know how to organize data in a way that pertinent information and conclusions can be extracted
11. explain the means by which we can measure the dispersion of a reported data set
12. describe what we mean by a probability distribution and the characteristics of a probability distribution of that has a bell shaped curve
13. explain how cash flow diagrams is used in analysis of engineering economics problems and give examples
14. Explain what they mean and how they differ and give examples
15. know how to compute the future work of any present amount and present worth of any future amount
16. explain what effective interest rate means and give examples
17. Understand how to use engineering economic principles to select the best alternative from among many choices

Suggested Activities & Best Practices

- Lab Reports
- Prototyping
- Problem Based Learning Experience
- Power Points with Notes
- Homework and Classwork Activities
- Group Activities
- In Class Discussion
- Do Nows and Closures
- Class Polling Observation

Assessment Evidence - Checking for Understanding (CFU)

Chapter Quizzes and Tests (Summative)

Socratic Questioning (Formative)

Lab Journal (Alternative)

Common Department Benchmark (Benchmark)

Oncourse Assessment Tools (Formative)

Do Now and Exit Tickets (Formative)

- Admit Tickets
- Common Benchmarks

- Compare & Contrast
- Define
- Describe
- Evaluate
- Evaluation rubrics
- Exit Tickets
- Explaining
- Illustration
- Journals
- KWL Chart
- Multimedia Reports
- Newspaper Headline
- Quizzes
- Self- assessments
- Socratic Seminar
- Surveys
- Teacher Observation Checklist
- Think, Pair, Share
- Top 10 List
- Unit review/Test prep
- Unit tests
- Web-Based Assessments
- Written Reports

Primary Resources & Materials

Moaveni, Saeed. *Engineering Fundamentals: an Introduction to Engineering*. Cengage Learning, 2016.

Ancillary Resources

Ancillary Resources

Teacher and Publisher supplied power points, notes, guides, labs, and worksheets

Resource manuals

Internet Resources

Computer Activities

American Academy of Environmental Engineers - www.aaees.org

American Institute of Aeronautics and Astronautics - www.aiaa.org

American Institute of Chemical Engineers www.aiche.org

The American Society of Agricultural and Biological Engineers - www.asabe.org

American Society of Civil Engineers - www.asce.org

American nuclear Society - www. ans.org

American Society of Heating, Refrigeration and Air Conditioning Engineers - www.ashrae.org

American Society of Mechanical Engineers - www.asme.org

Biomedical Engineering Society - www.bmes.org

Institute of electrical and Electronics Engineers - www.ieee.org

The Institute of Industrial Engineers - www.iienet2.org

National Academy of Engineering - www.nae.edu

National Science Foundation - www.nsf.gov

National Society of Black Engineers - www.nsbe.org

National Society of Professional Engineers - www.nspe.org

Society of Automotive Engineers - www.sae.org

Society of Hispanic Professional Engineers - www.shpe.org

Society of Manufacturing Engineers - www.sme.org

Society of Women Engineers - www.swe.org

Tau Beta Pi - All Engineering Honor Society - www.tbp.org

NASA Centers Ames Research Center - www.arc.nasa.gov

Dryden Flight Research Center - www.dfrc.nasa.gov

Goddard Space Flight Center - www.gsfc.nasa.gov

Jet Propulsion Laboratory - www.jpl.nasa.gov

Johnson Space Center - www.jsc.nasa.gov

Kennedy Space Center - www.larc.nasa.gov

Free Patents Online - http://www.freepatentsonline.com/

National Academy of Engineering Grand Challenges - http://www.engineeringchallenges.org/

Try Engineering - http://tryengineering.org/

Teach Engineering - https://www.teachengineering.org/

USPTO kids - http://www.uspto.gov/kids/

National Technology Students Association and NJ TSA - http://www.tsaweb.org/ and http://njtsa.pages.tcnj.edu/

Technology Infusion

Gizmos

Near POD

Google Classroom

JamBoards

3D Printer

CAD

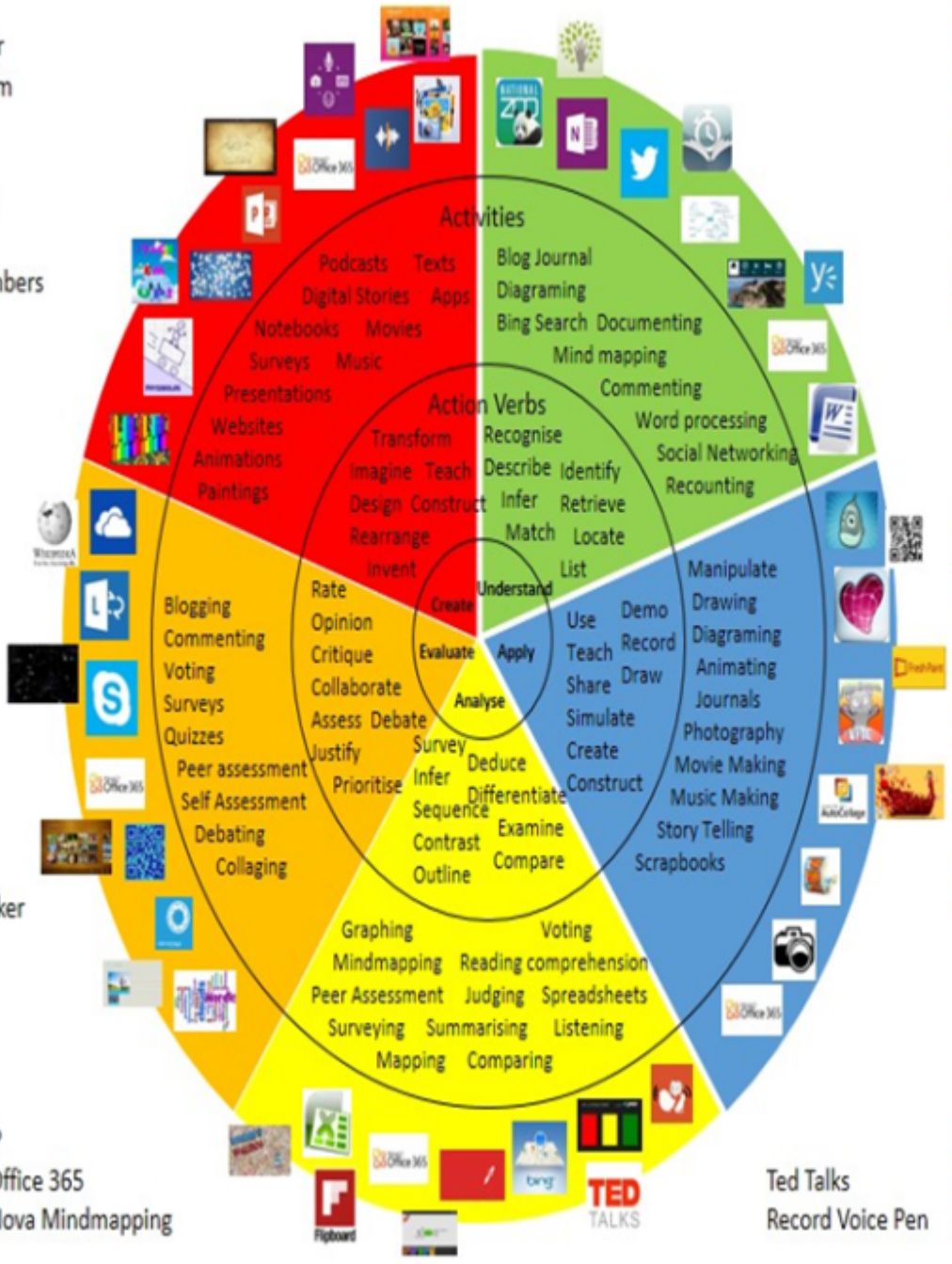
Win 8.1 Apps/Tools Pedagogy Wheel

Podcasts
Photostory 3
Kid Story Builder
Music Maker Jam
Paint A Story
Office 365
MS PowerPoint
Stack 'Em Up
NqSquared Numbers
Physamajig
Xylophone 8

Wikipedia
Skydrive
Lync
SkyMap
Skype
Office 365
Puzzle Touch
Easy QR
Memorylage
Life Moments
Word Cloud Maker

Where's Waldo?
MS Excel
Flipboard
Office 365
Nova Mindmapping

Ted Talks
Record Voice Pen



Originally taken from http://www.coetail.com/vzimmer/files/2013/02/iPadagogy-Wheel.001.jpg
And adapted for Windows 8.1 devices by Charlotte Beckhurst @CharBeckhurst

Alignment to 21st Century Skills & Technology

- English Language Arts;
- Mathematics;
- Science and Scientific Inquiry (Next Generation);
- Social Studies, including American History, World History, Geography, Government and Civics, and Economics;
- World languages;
- Technology;
- Visual and Performing Arts.

CRP.K-12.CRP1.1	Career-ready individuals understand the obligations and responsibilities of being a member of a community, and they demonstrate this understanding every day through their interactions with others. They are conscientious of the impacts of their decisions on others and the environment around them. They think about the near-term and long-term consequences of their actions and seek to act in ways that contribute to the betterment of their teams, families, community and workplace. They are reliable and consistent in going beyond the minimum expectation and in participating in activities that serve the greater good.
CRP.K-12.CRP2.1	Career-ready individuals readily access and use the knowledge and skills acquired through experience and education to be more productive. They make connections between abstract concepts with real-world applications, and they make correct insights about when it is appropriate to apply the use of an academic skill in a workplace situation.
CRP.K-12.CRP3.1	Career-ready individuals understand the relationship between personal health, workplace performance and personal well-being; they act on that understanding to regularly practice healthy diet, exercise and mental health activities. Career-ready individuals also take regular action to contribute to their personal financial well-being, understanding that personal financial security provides the peace of mind required to contribute more fully to their own career success.
CRP.K-12.CRP4.1	Career-ready individuals communicate thoughts, ideas, and action plans with clarity, whether using written, verbal, and/or visual methods. They communicate in the workplace with clarity and purpose to make maximum use of their own and others' time. They are excellent writers; they master conventions, word choice, and organization, and use effective tone and presentation skills to articulate ideas. They are skilled at interacting with others; they are active listeners and speak clearly and with purpose. Career-ready individuals think about the audience for their communication and prepare accordingly to ensure the desired outcome.
CAEP.9.2.12.C.1	Review career goals and determine steps necessary for attainment.
CAEP.9.2.12.C.2	Modify Personalized Student Learning Plans to support declared career goals.

CAEP.9.2.12.C.3	Identify transferable career skills and design alternate career plans.
CAEP.9.2.12.C.4	Analyze how economic conditions and societal changes influence employment trends and future education.
CAEP.9.2.12.C.5	Research career opportunities in the United States and abroad that require knowledge of world languages and diverse cultures.
CAEP.9.2.12.C.6	Investigate entrepreneurship opportunities as options for career planning and identify the knowledge, skills, abilities, and resources required for owning and managing a business.
CAEP.9.2.12.C.7	Examine the professional, legal, and ethical responsibilities for both employers and employees in the global workplace.
TECH.8.1.12.A.1	Create a personal digital portfolio which reflects personal and academic interests, achievements, and career aspirations by using a variety of digital tools and resources.
TECH.8.1.12.A.2	Produce and edit a multi-page digital document for a commercial or professional audience and present it to peers and/or professionals in that related area for review.
TECH.8.1.12.A.3	Collaborate in online courses, learning communities, social networks or virtual worlds to discuss a resolution to a problem or issue.
TECH.8.1.12.A.4	Construct a spreadsheet workbook with multiple worksheets, rename tabs to reflect the data on the worksheet, and use mathematical or logical functions, charts and data from all worksheets to convey the results.
TECH.8.1.12.A.5	Create a report from a relational database consisting of at least two tables and describe the process, and explain the report results.
TECH.8.1.12.A.CS1	Understand and use technology systems.
TECH.8.1.12.A.CS2	Select and use applications effectively and productively.

21st Century Skills/Interdisciplinary Themes

- Communication and Collaboration
- Creativity and Innovation
- Critical thinking and Problem Solving
- ICT (Information, Communications and Technology) Literacy
- Information Literacy
- Life and Career Skills
- Media Literacy

21st Century Skills

- Civic Literacy
- Environmental Literacy
- Financial, Economic, Business and Entrepreneurial Literacy
- Global Awareness
- Health Literacy

Differentiation

Small Group Instruction

Study Guides

Project Based Learning

Differentiations:

- Small group instruction
- Small group assignments
- Extra time to complete assignments
- Pairing oral instruction with visuals
- Repeat directions
- Use manipulatives
- Center-based instruction
- Token economy
- Study guides
- Teacher reads assessments allowed
- Scheduled breaks
- Rephrase written directions
- Multisensory approaches
- Additional time
- Preview vocabulary
- Preview content & concepts
- Story guides
- Behavior management plan
- Highlight text
- Student(s) work with assigned partner
- Visual presentation
- Assistive technology
- Auditory presentations
- Large print edition
- Dictation to scribe
- Small group setting

Hi-Prep Differentiations:

- Alternative formative and summative assessments
- Choice boards
- Games and tournaments
- Group investigations

- Guided Reading
- Independent research and projects
- Interest groups
- Learning contracts
- Leveled rubrics
- Literature circles
- Multiple intelligence options
- Multiple texts
- Personal agendas
- Project-based learning
- Problem-based learning
- Stations/centers
- Think-Tac-Toes
- Tiered activities/assignments
- Tiered products
- Varying organizers for instructions

Lo-Prep Differentiations

- Choice of books or activities
- Cubing activities
- Exploration by interest
- Flexible grouping
- Goal setting with students
- Jigsaw
- Mini workshops to re-teach or extend skills
- Open-ended activities
- Think-Pair-Share
- Reading buddies
- Varied journal prompts
- Varied supplemental materials

Special Education Learning (IEP's & 504's)

Quiz and Test Study Guides

Graphic Organizers

Powerpoints posted on google classroom

- printed copy of board work/notes provided
- additional time for skill mastery
- assistive technology
- behavior management plan
- Center-Based Instruction
- check work frequently for understanding
- computer or electronic device utilizes
- extended time on tests/ quizzes
- have student repeat directions to check for understanding
- highlighted text visual presentation
- modified assignment format
- modified test content
- modified test format
- modified test length
- multi-sensory presentation
- multiple test sessions
- preferential seating
- preview of content, concepts, and vocabulary
- Provide modifications as dictated in the student's IEP/504 plan
- reduced/shortened reading assignments
- Reduced/shortened written assignments
- secure attention before giving instruction/directions
- shortened assignments
- student working with an assigned partner
- teacher initiated weekly assignment sheet
- Use open book, study guides, test prototypes

English Language Learning (ELL)

Peer to assist students

Allow tests and quizzes to be taken in ESL room with extra time

Students allowed to use electronic devices for translation

Word Lists provided

- teaching key aspects of a topic. Eliminate nonessential information
- using videos, illustrations, pictures, and drawings to explain or clarif
- allowing products (projects, timelines, demonstrations, models, drawings, dioramas, poster boards, charts, graphs, slide shows, videos, etc.) to demonstrate student's learning;
- allowing students to correct errors (looking for understanding)
- allowing the use of note cards or open-book during testing
- decreasing the amount of workpresented or required
- having peers take notes or providing a copy of the teacher's notes
- modifying tests to reflect selected objectives
- providing study guides
- reducing or omitting lengthy outside reading assignments
- reducing the number of answer choices on a multiple choice test
- tutoring by peers
- using computer word processing spell check and grammar check features
- using true/false, matching, or fill in the blank tests in lieu of essay tests

At Risk

Provide modified test

Tutoring times offered

Allow students to correct test for partial credit

Extended time for assignments

- allowing students to correct errors (looking for understanding)
- teaching key aspects of a topic. Eliminate nonessential information
- allowing products (projects, timelines, demonstrations, models, drawings, dioramas, poster boards, charts, graphs, slide shows, videos, etc.) to demonstrate student's learning
- allowing students to select from given choices
- decreasing the amount of workpresented or required
- having peers take notes or providing a copy of the teacher's notes
- marking students' correct and acceptable work, not the mistakes
- modifying tests to reflect selected objectives
- providing study guides
- reducing or omitting lengthy outside reading assignments
- reducing the number of answer choices on a multiple choice test
- tutoring by peers

- using authentic assessments with real-life problem-solving
- using videos, illustrations, pictures, and drawings to explain or clarify

Talented and Gifted Learning (T&G)

Provide enrichment articles and assignments

Allow students to complete independent study assignments

- Above grade level placement option for qualified students
- Advanced problem-solving
- Allow students to work at a faster pace
- Higher order, critical & creative thinking skills, and discovery
- Multi-disciplinary unit and/or project
- Utilize exploratory connections to higher-grade concepts
- Utilize project-based learning for greater depth of knowledge