PLANNED INSTRUCTION

A PLANNED COURSE FOR:

Senior Science Research Seminar

Grade Level: 12

Date of Board Approval: _____2016_____

DELAWARE VALLEY SCHOOL DISTRICT

Planned Instruction

Title of Planned Instruction: Senior Science Research Seminar

Subject Area: Science Grade(s): 12

Course Description: Students design, conduct, and report the results of a (school) yearlong independent research project on a science topic of their choice. Science Department faculty members guide the students through the process, but the majority of the work on the project is the individual responsibility of the student. Students write a daily report, in a laboratory notebook, describing the progress of their project. Students read biology, chemistry, and physics articles from scientific journals. Students use those journal articles as models for writing, and rewriting, a scientific paper describing the results of their independent research project. Students use mathematics for describing theoretical models and statistics for analyzing experimental results. The final outcome of the course is a scientific paper describing the results of the independent research project and a public presentation summarizing and defending that paper. In addition to science, this course stresses integrating mathematics, reading, writing, and speaking into the project. This course is designed for highly motivated students of exceptional ability who have a strong interest in science. Students should also be enrolled in or have already completed one of the science AP courses.

Time/Credit for the Course: Meets for 46 minutes daily for a yearly total of 138 hours of instruction. One secondary level credit is to be awarded for satisfactory completion

Curriculum Writing Committee: Steve Rhule

Curriculum Map

1. **Marking Period One -Overview with time range in days:**
   Unit 1: Designing Experiment – 45 days

Marking Period One - Goals:

Understanding of:

- Experimental Design
  - Create project schedule for 1st marking period
  - Develop idea for project
  - Write daily laboratory notebook entries describing work on project
  - Survey existing research related to project idea
  - Write first draft of a specific and testable hypothesis to test project idea
  - Design experiment to test hypothesis
  - Sample existing biology, chemistry, and physics articles from scientific journals with emphasis on Materials and Methods
  - Write first draft of experimental protocol
  - Conduct pre-experiment trials
  - Revise experimental protocol
  - Begin experimental trials and data collection

- Technology Use
  - Create schedule using software
  - Write technical paper using software
  - Survey existing research using internet
  - Collect data using computer hardware, including probes, interfaces, computers, and software
  - Analyze data using computer software
  - Summarize and present preliminary results using software
  - Communicate work using Google Drive
  - Present experimental results using software

- Technical Writing
  - Write daily progress reports
  - Create and update (weekly) project schedule
  - Write and revise experimental protocol
  - Write first draft of technical paper Introduction and References, using American Psychological Association (APA) style
  - Write first draft of technical paper Materials and Methods, using American Psychological Association (APA) style

- Mathematics Use
  - Analyze relationships
  - Make predictions
  - Develop and interpret models

2. Marking Period Two -Overview with time range in days:

Unit 2: Conducting Experiment – 45 days

Marking Period Two - Goals:

Understanding of:

- Data collection and analysis
  - Continue to write daily laboratory notebook entries describing work on project
  - Continue experimental trials and data collection
  - Continue to revise experimental protocol as needed
  - Read sample biology, chemistry, and physics articles from scientific journals with emphasis on Introduction and References
  - Organize experimental results
  - Write first draft of results
  - Select appropriate statistics for data analysis
  - Write first draft of data analysis
  - Conduct preliminary data analysis of data

- Technology Use
  - Create and revise schedule using software
  - Write and revise technical paper using software
  - Survey existing research using internet
  - Data collection using computer hardware, including probes, interfaces, computers, and software
  - Data analysis using computer software
  - Summarize and present preliminary results using software
  - Communicate work using Google Drive
  - Presentation of experimental results using software

- Technical Writing
  - Write daily progress reports
  - Create and update (weekly) project schedule
  - Revise experimental protocol
  - Write second draft of Introduction and References based on editorial comments on first draft supplied by instructors
  - Write first draft of technical paper Results and Analysis, using American Psychological Association (APA) style
  - Write first draft of technical paper Title Page, Table of Contents, and Appendix, using American Psychological Association (APA) style

- Mathematics Use
  - Analyze relationships
  - Make predictions
  - Develop and interpret models
  - Statistical analysis of data

3. Marking Period Three -Overview with time range in days:

Unit 3: Data Analysis and Conclusion – 45 days

Marking Period Three -Goals

Understanding of:

- Using Data to Form Conclusions
  - Continue to write daily laboratory notebook entries describing work on project
  - Continue experimental trials and data collection
  - Continue to revise experimental protocol as needed
  - Read sample biology, chemistry, and physics articles from scientific journals with emphasis on Results, Analysis, and Conclusion
  - Conduct statistical analysis of experimental results
  - Write first draft of Conclusion

- Technology Use
  - Create and revise schedule using software
  - Write and revise technical paper using software
  - Survey existing research using internet
  - Data collection using computer hardware, including probes, interfaces, computers, and software
  - Data analysis using computer software
  - Summarize and present preliminary results using software
  - Communicate work using Google Drive
  - Presentation of experimental results using software

- Technical Writing
  - Write daily progress reports
  - Create and update (weekly) project schedule
  - Revise experimental protocol
  - Write third draft of Introduction and References based on editorial comments on second draft supplied by instructors
  - Write second draft of technical paper Results and Analysis based on editorial comments on first draft supplied by instructors
  - Write first draft of technical paper Conclusion, using American Psychological Association (APA) style
  - Combine Title Page, Table of Contents, Introduction, Materials and Methods, Results and Analysis, Conclusion, References, and Appendix into APA style technical paper

- Mathematics Use
  - Analyze relationships
  - Make predictions
  - Develop and interpret models
  - Statistical analysis of data
  - Form appropriate conclusions based on statistical analysis

4. Marking Period Four –Overview with time range in days:

Unit 4: Communicate Project – 45 days

Marking Period Four -Goals:

Understanding of:

- Effectively Communicating Results
  - Continue to write daily laboratory notebook entries describing work on project
  - Finish experimental trials and data collection
  - Finish analysis of data
  - Form final conclusions
  - Finish technical paper describing project
  - Create presentation summarizing technical paper
  - Deliver presentation before audience including: students, parents, invited guests, school board members, administrators, and teachers

- Technology Use
  - Create and revise schedule using software
  - Write and revise technical paper using software
  - Survey existing research using internet
  - Data collection using computer hardware, including probes, interfaces, computers, and software
  - Data analysis using computer software
  - Summarize and present preliminary results using software
  - Communicate work using Google Drive
  - Presentation of experimental results using software

- Technical Writing
  - Write daily progress reports
  - Create and update (weekly) project schedule
  - Revise experimental protocol
  - Write final draft of Introduction and References based on editorial comments on third draft supplied by instructors
  - Write final draft of technical paper Results and Analysis based on editorial comments on second draft supplied by instructors
  - Write final draft of technical paper Conclusion based on editorial comments on second draft supplied by instructors
  - Write and revise, based on editorial comments, technical paper Abstract
  - Assemble final draft of technical paper, including: Title Page, Abstract, Table of Contents, Introduction, Materials and Methods, Results and Analysis, Conclusion, References, and Appendix into APA style technical paper
  - Create, rehearse, and revise presentation summarizing technical paper

- Mathematics Use
  - Analyze relationships
  - Make predictions
  - Develop and interpret models
  - Statistical analysis of data
  - Form appropriate conclusions based on statistical analysis

UNIT 1: Designing Experiment

Big Idea #1: Question and Explore

Scientific inquiry and investigation occur when students are exposed to scientific problems that stimulate their intellectual curiosity. Students then develop a critical question to answer around that problem. A review of existing literature related to the question provides an opportunity for exploration of competing opinions, the context of those opinions, and the credibility of those opinions. The literature review leads students to synthesize other researcher's ideas and develop their own perspectives and not just accept the opinions of others. The students consider the purpose of their research project, what they hope to discover and why. Ideally, students will develop additional questions that may lead to further inquiry. Students learn how scientific questions are asked and answered, the process of an indepth investigation stimulates student curiosity and leads to meaningful discoveries.

Essential Questions:

- What questions have not been asked?
- What do I want to know?
- What do I want to learn?
- What do I want to understand?
- How does my research question shape the process of trying to answer that question?
- How does my project purpose shape the research leading to achieve that purpose?

Concepts:

- Examining the perspectives and ideas of others often leads to questions for further investigation.
- Inquiry begins with identifying a problem, focusing on the scope of interest, and understanding where the problem exists in a larger context.
- Good research questions are open-ended and lead to an examination that includes the complexity of a problem.
- The inquiry process allows for curiosity and imagination to be incorporated with ideas and exploration.
- Inquiry topics originate from personal interest, passion for a field, desire to understand, or wish to address an issue.
- The inquiry process involves exploring the existing knowledge associated with the topic. Researching the existing knowledge may lead to the discovery of connections that can increase understanding and lead to further questions.
- Scientific research addresses various problems (e.g., practical, theoretical, interpretive, aesthetic) and/or tests or extends an existing idea.
- A research question/project goal emerges from the scientist's purpose (i.e., to explore, explain, and create).
- A research question/project goal often requires multiple revisions to ensure it is appropriate in terms of time and resources.
- A variety of strategies (e.g., brainstorming, concept mapping, prewriting, exploration of space, drafting) can be used to illustrate, organize, and connect ideas.
- Inquiry confirms or challenges one's existing understandings, assumptions, beliefs, and/or knowledge.

- Information used to address a problem may come from various secondary sources (e.g., articles, other studies, analyses, reports) and/or primary sources (e.g., original texts and works, material culture, or personally collected data such as from experiments, surveys, questionnaires, interviews, observations, personal narratives).
- Advanced search tools, Boolean logic, and key words allow scientists to refine, focus, and/or limit their searches based on a variety of factors (e.g., date, peer-review status, type of publication).
- Consulting the bibliographies of primary sources may provide additional ideas or resources.
- Social media may be used as a potential source of information, but an understanding of its limitations is necessary to maintain credibility.
- Software (e.g., Word, Excel) and online tools (e.g. citation generators) are used by researchers to manage and catalog sources and produce reference lists.
- Software and online tools (e.g. Google Drive, SurveyMonkey) can be used to survey participants and analyze large data sets.
- The scope and purpose of one's research and the credibility of sources affects the validity of the conclusions.
- Credibility of evidence depends on use of sources and data that are relevant and reliable (current, authoritative).
- Determining the credibility of a source requires considering and evaluating the reputation and credentials of the author, publisher, site owner, and/or sponsor, understanding and evaluating the author's perspective and research methods; and considering how others respond to their work. Scientific articles are often peer-reviewed, meaning the research has been reviewed and accepted by disciplinary experts.
- When gathering data on individual's behaviors, attitudes, and preferences, the accuracy and validity of such data depends on the honesty, memory, and reliability of the respondents and/or observers as well as the design of the data collection instrument.
- The way the problem is posed, situated, framed, or contextualized will guide the inquiry process and influence the type of information needed and appropriate method of gathering it.
- Methods for data collection, analysis, innovation, and/or interpretation should be aligned with the research question/project goal.
- Inquiry may include qualitative, quantitative, or mixed research methods. The researcher may adjust the course of inquiry and/or develop different tools, methods, and processes as the research progresses.
- Based on the research question or project goal, methods of data or information collection may be qualitative (e.g., open-ended survey questions, interviews, observational notes, interpretation of texts); may be quantitative (e.g., precise measurements, modeling, using structured and validated data collection instruments and procedures); or could include a combination of both qualitative and quantitative.
- Data or information may be analyzed in a variety of ways appropriate to the inquiry.
- Scientists identify reasons for choosing a sample of information, a population, or artifacts and understand the limits of the inferences or conclusions made based on the sample chosen
- Descriptive or inferential statistics can be used to display and/or analyze data.

- Data/information may be organized and categorized (or coded) to identify patterns or themes.
- Qualitative and quantitative data/information may be combined to triangulate and corroborate trends, patterns, correlations, and/or themes.
- Methods of inquiry, analysis, and other feasible research activities, are planned while taking into account deadlines, priorities, risks, setbacks, and the availability of resources.
- Setbacks are inevitable; scientists/researchers need to focus on the essential goals of the inquiry or project and be prepared to try alternate approaches to achieve those goals.
- Experts in the field may provide guidance and/or discipline-specific knowledge or perspective. Scientists must learn how to seek advice while maintaining self-sufficiency.
- Scientists have ethical and moral responsibilities when they conduct research.
- There are laws, rules, school policies, and other guidelines that govern the conduct of scientists, in particular when studies involve humans and animals. Accordingly, scientists gain approval to conduct research with humans through an institutional review board (IRB).
- There are copyright and patent laws and guidelines that govern the use and reproduction of other's instruments, work, personal information, and intellectual property.

Competencies:

- Identifying and contextualizing a problem or issue.
- Posing complex questions and seeking out answers that reflect multiple, divergent, or contradictory perspectives.
- Identifying a topic of inquiry.
- Articulating the purpose and significance of the scholarly inquiry.
- Developing and revising a focused research question/project goal.
- Retrieving, questioning, organizing, and using prior knowledge about a topic.
- Accessing and managing information using effective strategies.
- Identifying the information needed and selecting appropriate strategies to find or collect it.
- Designing, planning, and implementing a scientific inquiry
- Demonstrating perseverance through setting goals, managing time, and working independently on a long-term project.
- Employing ethical research practices.

Big Idea #2: Understand and Analyze

Developing an understanding of a research topic begins with comprehension of the existing concepts and perspectives related to that topic. Explaining the relevant ideas of a research source requires identifying and then summarizing those ideas. Students gain understanding when they summarize and explain an author's perspective. Understanding an author's perspective is essential to an analysis of a source. That analysis; including consideration of the author's point of view and purpose; the reasoning and details the author selects, develops, and conveys; and the way the author places those details, may lead to a greater understanding of the concept being explored. Students evaluate the validity of an argument by examining the strength of the author's reasoning and the quality of the evidence cited by that author. The goal is for the student to understand the information contained in the research source and incorporate that information into their project.

Essential Questions:

- What strategies will help me understand a research source?
- What is the main idea of the source and how did the author develop that idea?
- What biases may have influenced the perspective of the author of the source?
- What other perspectives are acknowledged by the author of the source?
- How can the quality of the source be assessed?

Concepts:

- Critically reading the source to identify the main idea, tone, assumptions, context, perspective, reasoning, and evidence used by the author.
- Using preview strategies (e.g., including but not limited to, skimming, scanning, rereading, questioning, etc.) to preview and prioritize research sources.
- Using active reader strategies (e.g., annotating, note-taking, highlighting, reading aloud, etc.) to create meaning from a research source.
- The main idea of a source is often expressed in the thesis statement, the conclusion, and implied throughout the work.
- Authors support their arguments with claims justified by evidence.
- Lack of a complete understanding of a source may lead to oversimplification and/or generalization.
- Inductive reasoning uses specific observations and/or data points to identify trends, make generalizations and draw conclusions.
- Deductive reasoning uses broad facts or generalizations to generate additional, more specific conclusions.
- An argument's line of reasoning is organized to show causality, to define, to propose a solution, or to lead to a conclusion.
- Effective arguments acknowledge other arguments and respond to them with rebuttal, refutation, and/or concession counterarguments.
- An argument's time and purpose, and its relation to other arguments are considered when interpreting that argument.
- Authors use qualitative and/or quantitative evidence, with varying degrees of validity, to support their claims.
- Authors include evidence strategically in order to support their claims.
- Authors use language, authority, qualifiers, and emphasis to appeal to, and possibly manipulate, their readers.
- Comparative, causal, or correlational evidence may be used to identify and explain relationships and/or patterns and trends.
- Credibility may be compromised when an author fails to acknowledge and/or consider the limitations of their conclusions, opposing views, and/or their own biases.
- An argument is valid when there is logical consistency between the path of reasoning and the conclusion.
- Validity of an argument is most often achieved when the conclusion is aligned with the evidence.
- The strength of an argument depends on the author acknowledging and/or considering the limitations of their conclusions, opposing views, and/or their own biases.
- Conclusions are contextual and their validity must be affirmed, qualified, or refuted.

- Researchers analyze and evaluate other's work in terms of that work's alignment of purposes, goals, and methods of inquiry.
- An argument's implications and consequences may be intended or unintended.
- Significant arguments can influence behavior and have real-world impact.

Competencies:

- Employing appropriate reading strategies and reading critically for a specific purpose.
- Summarizing and explaining a source's main idea without making faulty generalizations and oversimplifications.
- Summarizing and explaining the reasoning of an argument.
- Identifying, explaining, and analyzing the logic and line of reasoning of an argument.
- Describing and analyzing the relevance and credibility of evidence used to support an argument, taking context into consideration.
- Evaluating the validity of an argument.
- Evaluating and critiquing other's inquiries, studies, and perspectives.
- Connecting an argument to broader issues by examining the implications of the author's claim.
- Evaluating potential resolutions, conclusions, or solutions to problems or issues raised by an argument.

Big Idea #3: Evaluate Multiple Perspectives

Comparing and contrasting multiple perspectives will help students to better understand the complexities of a problem they are investigating. Students look at supporting, opposing, and competing viewpoints and consider the assumptions and biases underlying those perspectives.

Essential Questions:

- What patterns or trends can be identified among the arguments about the problem?
- What are the consequences of accepting or rejecting a specific argument?
- How are the multiple perspectives connected?
- What other issues, questions, or topics are related to the different arguments?
- How can the contradictions between the viewpoints be resolved or explained?
- What is the perspective of the source of the information?

Concepts:

- An individual's viewpoint is influenced by his/her education, experiences, culture, and environment.
- Perspectives may be oppositional, concurring, complementary, or competing.
- Ideas may be ambiguous or not well defined.
- The processes of identification and interpretation may not lead to a definitive answer to a question.
- Critical thinkers know that arguments may be based on emotion, values, personal biases, assumptions, and logic.
- Critical thinkers are aware that their own evaluation of arguments and viewpoints may be affected by their own biases.

Competencies:

- Identifying, comparing, and interpreting multiple perspectives on or arguments about a problem.
- Evaluating objections, implications, and limitations of alternate, opposing, or competing perspectives or arguments.

Big Idea #4: Synthesize Ideas

Once enough information is gathered and evaluated, students synthesize their accumulated knowledge, emerging ideas, and perspectives to form conclusions of their own. Students must consider other points of view but also analyze material to develop their own perspectives and scholarly works. The goal is for students to think critically about the information and then add to, not simply repeat, the ideas of others. In this way, students establish a unique, creative voice within the larger conversation.

Essential Questions:

- How do I connect and analyze the evidence in order to develop an argument and support a conclusion?
- Are there other conclusions I should consider?
- How does my work emerge from my perspective?
- How do I account for my biases and assumptions?
- What is the most appropriate way to use other's work to support my argument?
- How do I guarrantee that the conclusions I form are my own?

Concepts:

- Effective arguments use reason and evidence to convey a perspective or point of view stated in a thesis and/or conclusion.
- Effective arguments are supported by connected claims, reasons, and evidence.
- Effective arguments increase credibility and decrease overgeneralization and oversimplification by placing limits on claims.
- Effective arguments may acknowledge and respond to contradictory arguments using concession, refutation, and/or rebuttal.
- Effective arguments use a clear and logical path of reasoning to guide the reader to a conclusion.
- The logic of an argument may be deductive (claim followed by evidence) or inductive (evidence followed by a conclusion).
- A line of reasoning is organized based on the argument's purpose.
- Claims and supporting evidence are arranged to convey reasoning and relationship.
- The same argument may be organized, arranged, or supported in multiple ways, depending on the audience and the context.
- Whether developing an argument or conceptualizing an idea, a researcher must thoughtfully choose and implement a process aligned with the project goal.
- Each discipline has its own conventions and manners of communicating.
- Researchers apply discipline-specific terminology in their analysis.
- Different disciplines methods for learning and evaluating information may be discovered through engaging with discipline-specific foundational texts and works.
- Disciplines may be either broadly or narrowly defined.
- Different disciplines may be combined to provide new perspectives.

- Evidence can be from print sources, experts, or data collected in surveys and experiments.
- Evidence is used to support the claims and reasoning of an argument. Compelling evidence is sufficient, accurate, relevant, current, and credible.
- Evidence is chosen to align an argument with authority, define a concept, illustrate a process, clarify a statement, set a mood, provide an example, and/or to qualify a point.
- Commentary connects the chosen evidence to the claim through interpretation or inference, identifying patterns, describing trends, and/or explaining relationships.
- Plagiarism is a serious offense that occurs when a person presents another's ideas or words as his or her own. Plagiarism may be avoided by acknowledging sources thoroughly and accurately.
- Source material should be introduced, integrated, or embedded into the text of an argument.
- Quoted and paraphrased material must be properly attributed, credited, and cited following a style manual.
- Academic disciplines use specific style guides for citing and attributing sources (e.g., APA, MLA, Chicago, AMA).
- Innovative solutions and arguments identify and challenge assumptions, acknowledge the importance of content, imagine and explore alternatives, and engage in reflective skepticism.
- When making choices and proposing solutions, the advantages and disadvantages of the options should be weighed against the goal.

Competencies:

- Formulating a complex and well-reasoned argument.
- Selecting and consistently applying an appropriate disciplinary approach to form a scientific argument.
- Interpreting, using, and synthesizing qualitative and/or quantitative data from various sources (e.g. primary, secondary, print, non-print) to develop and support an argument.
- Providing insightful and cogent commentary that links evidence with claims.
- Attributing knowledge and ideas accurately and ethically using an appropriate citation style.
- Extending an idea, question, process, or product to innovate or create new understandings.
- Offering resolutions, conclusions, and/or solutions based on evidence as well as considering consequences and implications.

Big Idea #5: Technology Use

Technology is created, used, and modified by humans.

Essential Questions:

- What knowledge and skills are essential for humans to make sound decisions about creating, using, and modifying technologies?

Concepts:

- Decisions about the use of products and systems can result in known and unexpected consequences.

- The study of the impacts of technological systems enables us to plan and direct technological developments.
- The goal of technology is to improve the human condition by maximizing positive impacts and minimizing negative one.
- While science is the study of the natural world, technology is the study of the human designed world.
- Science and technology are inextricably connected and are driven by human decision making.

Competencies:

- Analyze decisions related to the use of technology, predict consequences and compare with the results of the designed system
- Design, build, and test/evaluate a technological system to analyze its positive and negative consequences and impacts on individuals, societal institutions and our environment.
- Apply scientific and mathematical principles to an advanced engineering design problem then build and assess it.
- Maintain an engineering design journal that documents the complementary roles of science and math concepts in the engineering design process.
- Design, produce and transmit a message through a technological channel then analyze the effectiveness in terms of the initial goals.

Big Idea #6: Technology Literacy

Technological literacy is the ability to use, assess and manage technology around us.

Essential Questions:

- What is the importance of technological literacy?

Concepts:

- Technology and society mutually impact each other.
- Technological literacy is the ability to understand, use, assess, design, and produce technology (i.e. Invention & Innovation).
- Technological literacy is required for all citizens in a democratic society for shared decision-making.
- Technological literacy is necessary for a productive 21st century skilled workforce.
- Technological literacy is a lifetime endeavor.
- People select, create, and use science and technology and are limited by constraints (e.g. social and physical).

Competencies:

- Design, produce, test and analyze a technological solution that has desirable impacts on a culture that improves local, regional, or global economic conditions.
- Use current technological systems efficiently, identify undesirable results, then design, produce, test and utilize engineering analysis to optimize solutions.
- Demonstrate, model and communicate how societies depend on technology to use information, physical and bio-related systems to create desirable solutions to human needs and wants.

- Design, produce, test and analyze systems that use technological resources for the purpose of improving on existing technologies to impact individual lives, societies, our world, and the environment.
- Debate current technological issues and opportunities using informed decision making in a democratic society.
- Identify how specific technological inventions and innovations are constrained by the natural and legislative world in various societies.

Big Idea #7: Technology Design

Technological design is a creative process that anyone can do which may result in new inventions and innovations.

Essential Questions:

- How would you explain and apply technological design and problem solving methods in the development of inventions and innovations?

Concepts:

- Technological design & problem solving utilizes a series of steps that take place in a well-defined sequence.
- Technological design & problem solving transforms an idea into a final product or system.
- Technological design & problem solving requires the application of hands-on abilities such as sketching, prototyping, and fabricating.
- Technological design & problem solving includes both formative and summative analysis.
- Technological design & problem solving requires the ability to clearly communicate engineered solutions.

Competencies:

- Employ engineering design and problem solving skills to solve complex technological challenges.
- Transform ideas into technological products and/or systems using a focused engineering design process.
- Utilize computer-aided engineering design software to solve advanced, real-world technological problems.
- Document progress through the engineering design process using a journal that synthesizes the process and results.
- Evaluate the effectiveness of engineered solutions through written, spoken, mathematical, and graphical means.

Big Idea #8: Technology Developments

A technological world requires that humans develop capabilities to solve technological challenges and improve products for the way we live.

Essential Questions:

- How have technological developments impacted devices, processes, and systems to fulfill human wants and needs?

Concepts:

- The abilities required in a technological world include diagnosing, troubleshooting, analyzing and maintaining systems.
- Innovation is the process of modifying an existing product, process, or system to improve it.
- Invention is a process of turning ideas and imagination into new products, processes, or systems.
- Safety is a preeminent concern for all technological development and use.
- In a technological world, inventions and innovations must be carefully assessed by individuals and society as a whole.

Competencies:

- Use and maintain technological products and systems and describe their functions, advantages/disadvantages and hazards/benefits.
- Through a structured engineering design process, select an existing product and design, build, and assess an improved version.
- Utilize a structured innovation process to create a new product, process or system.
- Use tools and machines safely and explain the common and particular hazards of specific technological devices.
- Assess the origins and importance of specific technological inventions and innovations and predict future impacts of proposed technologies.
- Design a message, select a communication channel, produce and disseminate it and analyze its effectiveness.

Big Idea #9: Technology Characteristics

Each area of technology has a set of characteristics that separates it from others; however, many areas overlap in order to meet human needs and wants.

Essential Questions:

- How do various areas of technology influence the economy, the environment, society, and political decisions?

Concepts:

- Manufacturing is the process of turning raw materials into useful products.
- Construction is the process of turning raw materials into useful structures.
- Communication is the process of composing, sending, and receiving messages through technology.
- Transportation is the process of safely and efficiently moving people and products.
- Bio-related technologies are the processes of using biological organisms to make or modify products.
- Energy and power technologies are the processes of converting energy sources into useful power.

Competencies:

- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, manufacture, test, and analyze products that meet human needs and wants.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, construct, test, and analyze structures that meet human needs and wants.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, communicate, test, and analyze messages to meet human needs and wants.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, test, and analyze systems to transport people and products.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, test, and analyze bio-related products and systems to meet human needs and wants.

(There may be several Big Ideas and associated Essential Questions, Concepts, and Competencies within a unit.)

Curriculum Plan

Unit 1: Designing Experiment **Time Range in Days: 45 days**

Standard(s):

- Pennsylvania Academic Standards for Science and Technology and Engineering Education
- Pennsylvania Core Standards for Reading in Science and Technical Subjects
- Pennsylvania Core Standards for Writing in Science and Technical Subjects
- Pennsylvania Core Standards for Mathematics

(PA Academic Standards, PACS English/Language Arts, PACS Math, PACS Reading and Writing for Science and Technology, PACS Reading and Writing for History and Social Studies, National Standards)

Standards Addressed:

- 3.1.12.A9
- 3.4.12.C2
- 3.4.12.C3
- 3.4.12.D2
- 3.4.12.E6
- CC.3.5.11-12.A
- CC.3.5.11-12.B
- CC.3.5.11-12.C
- CC.3.5.11-12.D
- CC.3.5.11-12.G
- CC.3.5.11-12.H
- CC.3.5.11-12.I
- CC.3.5.11-12.J
- CC.3.6.11-12.A
- CC.3.6.11-12.B
- CC.3.6.11-12.C
- CC.3.6.11-12.D
- CC.3.6.11-12.E
- CC.3.6.11-12.F
- CC.3.6.11-12.G
- CC.3.6.11-12.H
- CC.3.6.11-12.I

(Number Only- See Appendix for Description)

Anchor(s):

- S11.A.1.1
- S11.A.1.2
- S11.A.1.3
- S11.A.2.1
- S11.A.2.2
- S11.A.3.1
- S11.A.3.2
- S11.A.3.3
- CC.2.3.HS.A.13
- CC.2.4.HS.B.2
- CC.2.4.HS.B.3
- CC.2.4.HS.B.5

(As Applicable)

Overview:

- Experimental design
- Problem solving
- Notebook writing
- Technical paper writing

Focus Question(s):

- What idea am I interested in investigating?
- What have others already discovered about my idea?
- What can I test about my idea?
- How can I conduct that test?

Goals:

- Project idea
- Hypothesis
- Experiment
- Technical paper
- Laboratory notebook

Objectives:

- Surveying existing research (DOK Level 2)
- Create project idea (DOK Level 4)
- Write specific and testable hypothesis (DOK Level 3)
- Summarize daily project work in laboratory notebook (DOK Level 2)
- Create technical paper describing project (DOK Level 4)
- Design experiment (DOK Level 4)

Core Activities and Corresponding Instructional Methods:

- Search scientific literature for information related to project
  - Discussion
  - Questioning
  - Surveying existing research
  - Independent reading
  - Laboratory notebook writing
  - Analyzing experimental results
  - Drawing conclusions from experimental results
- Create theoretical models to describe ideas involved in independent research project
  - Discussion
  - Questioning
  - Surveying existing research
  - Independent reading
  - Laboratory notebook writing
  - Analyzing experimental results
  - Drawing conclusions from experimental results
  - Scientific paper writing and rewriting
- Design scientific experiment to test theoretical model
  - Discussion
  - Questioning
  - Surveying existing research
  - Independent reading
  - Laboratory notebook writing
  - Laboratory experiments
  - Scientific paper writing and rewriting
- Write a technical paper describing project
  - Discussion
  - Questioning
  - Surveying existing research
  - Independent reading

  - Scientific paper writing and rewriting
  - Peer reviewing of other student's papers
- Summarize daily project work in laboratory notebook
  - Discussion
  - Questioning
  - Daily journal writing

Assessments:

Diagnostic:

- Daily progress reports written in laboratory notebooks
- Writing/rewriting technical paper

Formative:

- Suitable idea for independent research project investigation
- Design of scientific experiment investigating project idea
- Written drafts of an APA style scientific paper describing experiment
- Mathematical/Statistical analysis of experimental data
- Practice delivery of presentation summarizing scientific paper

Summative:

- Final draft of scientific paper describing completed independent research project
- Final draft of presentation summarizing scientific paper describing completed independent research project

Extensions:

- Biology, chemistry, physics articles from scientific journals
- Writing for science textbooks
- Statistics textbooks

Correctives:

- Science department faculty supervision
- Research scientist/consulting expert mentoring

Materials and Resources:

- Science department
  - laboratory equipment
  - Computers
  - Sensors
  - Interface equipment
- Google Drive
- American Psychological Association. (July 15, 2009). *Publication Manual of the American Psychological Association*, 6th edition. Washington, DC: American Psychological Association
- Freedman, R., Pisani, R., & Purves, R. (1998). *Statistics* (3rd ed.). New York: W. W. Norton & Company
- Moore, D. S. (1995). The Basic Practice of Statistics. New York: W. H. Freeman and Company
- Pechenik, J. A. (1997). *A Short Guide to Writing About Biology*. New York: Addison-Wesley
- Tufte, E. R. (1990). *Envisioning Information*. Chesire, CT: Graphics Press
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- *Technology Review*. Cambridge, MA: Massachusetts Institute of Technology

UNIT 2: Conducting Experiment

Big Idea #1: Question and Explore

Scientific inquiry and investigation occur when students are exposed to scientific problems that stimulate their intellectual curiosity. Students then develop a critical question to answer around that problem. A review of existing literature related to the question provides an opportunity for exploration of competing opinions, the context of those opinions, and the credibility of those opinions. The literature review leads students to synthesize other researcher's ideas and develop their own perspectives and not just accept the opinions of others. The students consider the purpose of their research project, what they hope to discover and why. Ideally, students will develop additional questions that may lead to further inquiry. Students learn how scientific questions are asked and answered, the process of an indepth investigation stimulates student curiosity and leads to meaningful discoveries.

Essential Questions:

- What questions have not been asked?
- What do I want to know?
- What do I want to learn?
- What do I want to understand?
- How does my research question shape the process of trying to answer that question?
- How does my project purpose shape the research leading to achieve that purpose?

Concepts:

- Examining the perspectives and ideas of others often leads to questions for further investigation.
- Inquiry begins with identifying a problem, focusing on the scope of interest, and understanding where the problem exists in a larger context.
- Good research questions are open-ended and lead to an examination that includes the complexity of a problem.
- The inquiry process allows for curiosity and imagination to be incorporated with ideas and exploration.
- Inquiry topics originate from personal interest, passion for a field, desire to understand, or wish to address an issue.
- The inquiry process involves exploring the existing knowledge associated with the topic. Researching the existing knowledge may lead to the discovery of connections that can increase understanding and lead to further questions.
- Scientific research addresses various problems (e.g., practical, theoretical, interpretive, aesthetic) and/or tests or extends an existing idea.
- A research question/project goal emerges from the scientist's purpose (i.e., to explore, explain, and create).
- A research question/project goal often requires multiple revisions to ensure it is appropriate in terms of time and resources.
- A variety of strategies (e.g., brainstorming, concept mapping, prewriting, exploration of space, drafting) can be used to illustrate, organize, and connect ideas.
- Inquiry confirms or challenges one's existing understandings, assumptions, beliefs, and/or knowledge.

- Information used to address a problem may come from various secondary sources (e.g., articles, other studies, analyses, reports) and/or primary sources (e.g., original texts and works, material culture, or personally collected data such as from experiments, surveys, questionnaires, interviews, observations, personal narratives).
- Advanced search tools, Boolean logic, and key words allow scientists to refine, focus, and/or limit their searches based on a variety of factors (e.g., date, peer-review status, type of publication).
- Consulting the bibliographies of primary sources may provide additional ideas or resources.
- Social media may be used as a potential source of information, but an understanding of its limitations is necessary to maintain credibility.
- Software (e.g., Word, Excel) and online tools (e.g. citation generators) are used by researchers to manage and catalog sources and produce reference lists.
- Software and online tools (e.g. Google Drive, SurveyMonkey) can be used to survey participants and analyze large data sets.
- The scope and purpose of one's research and the credibility of sources affects the validity of the conclusions.
- Credibility of evidence depends on use of sources and data that are relevant and reliable (current, authoritative).
- Determining the credibility of a source requires considering and evaluating the reputation and credentials of the author, publisher, site owner, and/or sponsor, understanding and evaluating the author's perspective and research methods; and considering how others respond to their work. Scientific articles are often peer-reviewed, meaning the research has been reviewed and accepted by disciplinary experts.
- When gathering data on individual's behaviors, attitudes, and preferences, the accuracy and validity of such data depends on the honesty, memory, and reliability of the respondents and/or observers as well as the design of the data collection instrument.
- The way the problem is posed, situated, framed, or contextualized will guide the inquiry process and influence the type of information needed and appropriate method of gathering it.
- Methods for data collection, analysis, innovation, and/or interpretation should be aligned with the research question/project goal.
- Inquiry may include qualitative, quantitative, or mixed research methods. The researcher may adjust the course of inquiry and/or develop different tools, methods, and processes as the research progresses.
- Based on the research question or project goal, methods of data or information collection may be qualitative (e.g., open-ended survey questions, interviews, observational notes, interpretation of texts); may be quantitative (e.g., precise measurements, modeling, using structured and validated data collection instruments and procedures); or could include a combination of both qualitative and quantitative.
- Data or information may be analyzed in a variety of ways appropriate to the inquiry.
- Scientists identify reasons for choosing a sample of information, a population, or artifacts and understand the limits of the inferences or conclusions made based on the sample chosen
- Descriptive or inferential statistics can be used to display and/or analyze data.

- Data/information may be organized and categorized (or coded) to identify patterns or themes.
- Qualitative and quantitative data/information may be combined to triangulate and corroborate trends, patterns, correlations, and/or themes.
- Methods of inquiry, analysis, and other feasible research activities, are planned while taking into account deadlines, priorities, risks, setbacks, and the availability of resources.
- Setbacks are inevitable; scientists/researchers need to focus on the essential goals of the inquiry or project and be prepared to try alternate approaches to achieve those goals.
- Experts in the field may provide guidance and/or discipline-specific knowledge or perspective. Scientists must learn how to seek advice while maintaining self-sufficiency.
- Scientists have ethical and moral responsibilities when they conduct research.
- There are laws, rules, school policies, and other guidelines that govern the conduct of scientists, in particular when studies involve humans and animals. Accordingly, scientists gain approval to conduct research with humans through an institutional review board (IRB).
- There are copyright and patent laws and guidelines that govern the use and reproduction of other's instruments, work, personal information, and intellectual property.

Competencies:

- Identifying and contextualizing a problem or issue.
- Posing complex questions and seeking out answers that reflect multiple, divergent, or contradictory perspectives.
- Identifying a topic of inquiry.
- Articulating the purpose and significance of the scholarly inquiry.
- Developing and revising a focused research question/project goal.
- Retrieving, questioning, organizing, and using prior knowledge about a topic.
- Accessing and managing information using effective strategies.
- Identifying the information needed and selecting appropriate strategies to find or collect it.
- Designing, planning, and implementing a scientific inquiry
- Demonstrating perseverance through setting goals, managing time, and working independently on a long-term project.
- Employing ethical research practices.

Big Idea #2: Synthesize Ideas

Once enough information is gathered and evaluated, students synthesize their accumulated knowledge, emerging ideas, and perspectives to form conclusions of their own. Students must consider other points of view but also analyze material to develop their own perspectives and scholarly works. The goal is for students to think critically about the information and then add to, not simply repeat, the ideas of others. In this way, students establish a unique, creative voice within the larger conversation.

Essential Questions:

- How do I connect and analyze the evidence in order to develop an argument and support a conclusion?

- Are there other conclusions I should consider?
- How does my work emerge from my perspective?
- How do I account for my biases and assumptions?
- What is the most appropriate way to use other's work to support my argument?
- How do I guarrantee that the conclusions I form are my own?

Concepts:

- Effective arguments use reason and evidence to convey a perspective or point of view stated in a thesis and/or conclusion.
- Effective arguments are supported by connected claims, reasons, and evidence.
- Effective arguments increase credibility and decrease overgeneralization and oversimplification by placing limits on claims.
- Effective arguments may acknowledge and respond to contradictory arguments using concession, refutation, and/or rebuttal.
- Effective arguments use a clear and logical path of reasoning to guide the reader to a conclusion.
- The logic of an argument may be deductive (claim followed by evidence) or inductive (evidence followed by a conclusion).
- A line of reasoning is organized based on the argument's purpose.
- Claims and supporting evidence are arranged to convey reasoning and relationship.
- The same argument may be organized, arranged, or supported in multiple ways, depending on the audience and the context.
- Whether developing an argument or conceptualizing an idea, a researcher must thoughtfully choose and implement a process aligned with the project goal.
- Each discipline has its own conventions and manners of communicating.
- Researchers apply discipline-specific terminology in their analysis.
- Different disciplines methods for learning and evaluating information may be discovered through engaging with discipline-specific foundational texts and works.
- Disciplines may be either broadly or narrowly defined.
- Different disciplines may be combined to provide new perspectives.
- Evidence can be from print sources, experts, or data collected in surveys and experiments.
- Evidence is used to support the claims and reasoning of an argument. Compelling evidence is sufficient, accurate, relevant, current, and credible.
- Evidence is chosen to align an argument with authority, define a concept, illustrate a process, clarify a statement, set a mood, provide an example, and/or to qualify a point.
- Commentary connects the chosen evidence to the claim through interpretation or inference, identifying patterns, describing trends, and/or explaining relationships.
- Plagiarism is a serious offense that occurs when a person presents another's ideas or words as his or her own. Plagiarism may be avoided by acknowledging sources thoroughly and accurately.
- Source material should be introduced, integrated, or embedded into the text of an argument.
- Quoted and paraphrased material must be properly attributed, credited, and cited following a style manual.
- Academic disciplines use specific style guides for citing and attributing sources (e.g., APA, MLA, Chicago, AMA).

- Innovative solutions and arguments identify and challenge assumptions, acknowledge the importance of content, imagine and explore alternatives, and engage in reflective skepticism.
- When making choices and proposing solutions, the advantages and disadvantages of the options should be weighed against the goal.

Competencies:

- Formulating a complex and well-reasoned argument.
- Selecting and consistently applying an appropriate disciplinary approach to form a scientific argument.
- Interpreting, using, and synthesizing qualitative and/or quantitative data from various sources (e.g. primary, secondary, print, non-print) to develop and support an argument.
- Providing insightful and cogent commentary that links evidence with claims.
- Attributing knowledge and ideas accurately and ethically using an appropriate citation style.
- Extending an idea, question, process, or product to innovate or create new understandings.
- Offering resolutions, conclusions, and/or solutions based on evidence as well as considering consequences and implications.

Big Idea #3: Technology Use

Technology is created, used, and modified by humans.

Essential Questions:

- What knowledge and skills are essential for humans to make sound decisions about creating, using, and modifying technologies?

Concepts:

- Decisions about the use of products and systems can result in known and unexpected consequences.
- The study of the impacts of technological systems enables us to plan and direct technological developments.
- The goal of technology is to improve the human condition by maximizing positive impacts and minimizing negative one.
- While science is the study of the natural world, technology is the study of the human designed world.
- Science and technology are inextricably connected and are driven by human decision making.

Competencies:

- Analyze decisions related to the use of technology, predict consequences and compare with the results of the designed system
- Design, build, and test/evaluate a technological system to analyze its positive and negative consequences and impacts on individuals, societal institutions and our environment.
- Apply scientific and mathematical principles to an advanced engineering design problem then build and assess it.

- Maintain an engineering design journal that documents the complementary roles of science and math concepts in the engineering design process.
- Design, produce and transmit a message through a technological channel then analyze the effectiveness in terms of the initial goals.

Big Idea #4: Technology Literacy

Technological literacy is the ability to use, assess and manage technology around us.

Essential Questions:

- What is the importance of technological literacy?

Concepts:

- Technology and society mutually impact each other.
- Technological literacy is the ability to understand, use, assess, design, and produce technology (i.e. Invention & Innovation).
- Technological literacy is required for all citizens in a democratic society for shared decision-making.
- Technological literacy is necessary for a productive 21st century skilled workforce.
- Technological literacy is a lifetime endeavor.
- People select, create, and use science and technology and are limited by constraints (e.g. social and physical).

Competencies:

- Design, produce, test and analyze a technological solution that has desirable impacts on a culture that improves local, regional, or global economic conditions.
- Use current technological systems efficiently, identify undesirable results, then design, produce, test and utilize engineering analysis to optimize solutions.
- Demonstrate, model and communicate how societies depend on technology to use information, physical and bio-related systems to create desirable solutions to human needs and wants.
- Design, produce, test and analyze systems that use technological resources for the purpose of improving on existing technologies to impact individual lives, societies, our world, and the environment.
- Debate current technological issues and opportunities using informed decision making in a democratic society.
- Identify how specific technological inventions and innovations are constrained by the natural and legislative world in various societies.

Big Idea #5: Technology Design

Technological design is a creative process that anyone can do which may result in new inventions and innovations.

Essential Questions:

- How would you explain and apply technological design and problem solving methods in the development of inventions and innovations?

Concepts:

- Technological design & problem solving utilizes a series of steps that take place in a well-defined sequence.
- Technological design & problem solving transforms an idea into a final product or system.
- Technological design & problem solving requires the application of hands-on abilities such as sketching, prototyping, and fabricating.
- Technological design & problem solving includes both formative and summative analysis.
- Technological design & problem solving requires the ability to clearly communicate engineered solutions.

Competencies:

- Employ engineering design and problem solving skills to solve complex technological challenges.
- Transform ideas into technological products and/or systems using a focused engineering design process.
- Utilize computer-aided engineering design software to solve advanced, real-world technological problems.
- Document progress through the engineering design process using a journal that synthesizes the process and results.
- Evaluate the effectiveness of engineered solutions through written, spoken, mathematical, and graphical means.

Big Idea #6: Technology Developments

A technological world requires that humans develop capabilities to solve technological challenges and improve products for the way we live.

Essential Questions:

- How have technological developments impacted devices, processes, and systems to fulfill human wants and needs?

Concepts:

- The abilities required in a technological world include diagnosing, troubleshooting, analyzing and maintaining systems.
- Innovation is the process of modifying an existing product, process, or system to improve it.
- Invention is a process of turning ideas and imagination into new products, processes, or systems.
- Safety is a preeminent concern for all technological development and use.
- In a technological world, inventions and innovations must be carefully assessed by individuals and society as a whole.

Competencies:

- Use and maintain technological products and systems and describe their functions, advantages/disadvantages and hazards/benefits.

- Through a structured engineering design process, select an existing product and design, build, and assess an improved version.
- Utilize a structured innovation process to create a new product, process or system.
- Use tools and machines safely and explain the common and particular hazards of specific technological devices.
- Assess the origins and importance of specific technological inventions and innovations and predict future impacts of proposed technologies.
- Design a message, select a communication channel, produce and disseminate it and analyze its effectiveness.

Big Idea #7: Technology Characteristics

Each area of technology has a set of characteristics that separates it from others; however, many areas overlap in order to meet human needs and wants.

Essential Questions:

- How do various areas of technology influence the economy, the environment, society, and political decisions?

Concepts:

- Manufacturing is the process of turning raw materials into useful products.
- Construction is the process of turning raw materials into useful structures.
- Communication is the process of composing, sending, and receiving messages through technology.
- Transportation is the process of safely and efficiently moving people and products.
- Bio-related technologies are the processes of using biological organisms to make or modify products.
- Energy and power technologies are the processes of converting energy sources into useful power.

Competencies:

- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, manufacture, test, and analyze products that meet human needs and wants.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, construct, test, and analyze structures that meet human needs and wants.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, communicate, test, and analyze messages to meet human needs and wants.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, test, and analyze systems to transport people and products.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, test, and analyze bio-related products and systems to meet human needs and wants.

(There may be several Big Ideas and associated Essential Questions, Concepts, and Competencies within a unit.)

Curriculum Plan

Unit 2: Conducting Experiment **Time Range in Days: 45 days**

Standard(s):

- Pennsylvania Academic Standards for Science and Technology and Engineering Education
- Pennsylvania Core Standards for Reading in Science and Technical Subjects
- Pennsylvania Core Standards for Writing in Science and Technical Subjects
- Pennsylvania Core Standards for Mathematics

Standards Addressed:

- 3.1.12.A9
- 3.4.12.C2
- 3.4.12.C3
- 3.4.12.D2
- 3.4.12.E6
- CC.3.5.11-12.A
- CC.3.5.11-12.B
- CC.3.5.11-12.C
- CC.3.5.11-12.D
- CC.3.5.11-12.G
- CC.3.5.11-12.H
- CC.3.5.11-12.I
- CC.3.5.11-12.J
- CC.3.6.11-12.A
- CC.3.6.11-12.B
- CC.3.6.11-12.C
- CC.3.6.11-12.D
- CC.3.6.11-12.E
- CC.3.6.11-12.F
- CC.3.6.11-12.G
- CC.3.6.11-12.H
- CC.3.6.11-12.I

(Number Only- See Appendix for Description)

Anchor(s):

- S11.A.1.1
- S11.A.1.2
- S11.A.1.3
- S11.A.2.1
- S11.A.2.2
- S11.A.3.1
- S11.A.3.2
- S11.A.3.3
- CC.2.3.HS.A.13
- CC.2.4.HS.B.2
- CC.2.4.HS.B.3
- CC.2.4.HS.B.5

(As Applicable)

Overview:

- Preliminary data collection
- Preliminary data analysis
- Experiment redesign
- Problem solving
- Notebook writing
- Technical paper writing

Focus Question(s):

- Does my data address my hypothesis?
- Is my experiment accomplishing what it was designed to do?
- How can I optimize my experiment?

- How will I analyze my data?

Goals:

- Experiment
- Data
- Technical paper
- Laboratory notebook

Objectives:

- Analyze preliminary data (DOK Level 4)
- Critique experiment (DOK Level 4)
- Redesign experiment (DOK Level 3)
- Summarize daily project work in laboratory notebook (DOK Level 2)
- Revise technical paper describing project (DOK Level 4)
- Create data analysis plan (DOK Level 4)

(Include DOK Levels)

Core Activities and Corresponding Instructional Methods:

- Conduct scientific experiment to collect preliminary data
  - Discussion
  - Questioning
  - Surveying existing research
  - Independent reading
  - Laboratory notebook writing
  - Laboratory experiments
  - Scientific paper writing and rewriting
- Solve problems that arise when experiment is run
  - Discussion
  - Questioning
  - Surveying existing research
  - Independent reading
  - Laboratory notebook writing
  - Laboratory experiments
  - Analyzing experimental results
  - Drawing conclusions from experimental results
- Redesign experiment to incorporate changes made to overcome problems
  - Discussion
  - Questioning
  - Surveying existing research
  - Independent reading
  - Laboratory notebook writing
  - Laboratory experiments
  - Analyzing experimental results
  - Drawing conclusions from experimental results
  - Scientific paper writing and rewriting
- Collect experimental data
  - Laboratory notebook writing

  - Laboratory experiments
  - Analyzing experimental results
  - Presenting experimental results
- Write a technical paper describing project
  - Discussion
  - Questioning
  - Surveying existing research
  - Independent reading
  - Scientific paper writing and rewriting
  - Peer reviewing of other student's papers
- Summarize daily project work in laboratory notebook
  - Discussion
  - Questioning
  - Daily journal writing

Assessments:

Diagnostic:

- Daily progress reports written in laboratory notebooks
- Writing/rewriting technical paper

Formative:

- Suitable idea for independent research project investigation
- Design of scientific experiment investigating project idea
- Written drafts of an APA style scientific paper describing experiment
- Mathematical/Statistical analysis of experimental data
- Practice delivery of presentation summarizing scientific paper

Summative:

- Final draft of scientific paper describing completed independent research project
- Final draft of presentation summarizing scientific paper describing completed independent research project

Extensions:

- Biology, chemistry, physics articles from scientific journals
- Writing for science textbooks
- Statistics textbooks

Correctives:

- Science department faculty supervision
- Research scientist/consulting expert mentoring

Materials and Resources:

- Science department
  - laboratory equipment
  - Computers
  - Sensors
  - Interface equipment

- Google Drive
- American Psychological Association. (July 15, 2009). *Publication Manual of the American Psychological Association*, 6th edition. Washington, DC: American Psychological Association
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- Tufte, E. R. (1997). *Visual Explanations*. Chesire, CT: Graphics Press
- *Technology Review*. Cambridge, MA: Massachusetts Institute of Technology

UNIT 3: Data Analysis and Conclusion

Big Idea # 1: Question and Explore

Scientific inquiry and investigation occur when students are exposed to scientific problems that stimulate their intellectual curiosity. Students then develop a critical question to answer around that problem. A review of existing literature related to the question provides an opportunity for exploration of competing opinions, the context of those opinions, and the credibility of those opinions. The literature review leads students to synthesize other researcher's ideas and develop their own perspectives and not just accept the opinions of others. The students consider the purpose of their research project, what they hope to discover and why. Ideally, students will develop additional questions that may lead to further inquiry. Students learn how scientific questions are asked and answered, the process of an indepth investigation stimulates student curiosity and leads to meaningful discoveries.

Essential Questions:

- What questions have not been asked?
- What do I want to know?
- What do I want to learn?
- What do I want to understand?
- How does my research question shape the process of trying to answer that question?
- How does my project purpose shape the research leading to achieve that purpose?

Concepts:

- Examining the perspectives and ideas of others often leads to questions for further investigation.
- Inquiry begins with identifying a problem, focusing on the scope of interest, and understanding where the problem exists in a larger context.
- Good research questions are open-ended and lead to an examination that includes the complexity of a problem.
- The inquiry process allows for curiosity and imagination to be incorporated with ideas and exploration.
- Inquiry topics originate from personal interest, passion for a field, desire to understand, or wish to address an issue.
- The inquiry process involves exploring the existing knowledge associated with the topic. Researching the existing knowledge may lead to the discovery of connections that can increase understanding and lead to further questions.
- Scientific research addresses various problems (e.g., practical, theoretical, interpretive, aesthetic) and/or tests or extends an existing idea.
- A research question/project goal emerges from the scientist's purpose (i.e., to explore, explain, and create).
- A research question/project goal often requires multiple revisions to ensure it is appropriate in terms of time and resources.
- A variety of strategies (e.g., brainstorming, concept mapping, prewriting, exploration of space, drafting) can be used to illustrate, organize, and connect ideas.
- Inquiry confirms or challenges one's existing understandings, assumptions, beliefs, and/or knowledge.

- Information used to address a problem may come from various secondary sources (e.g., articles, other studies, analyses, reports) and/or primary sources (e.g., original texts and works, material culture, or personally collected data such as from experiments, surveys, questionnaires, interviews, observations, personal narratives).
- Advanced search tools, Boolean logic, and key words allow scientists to refine, focus, and/or limit their searches based on a variety of factors (e.g., date, peer-review status, type of publication).
- Consulting the bibliographies of primary sources may provide additional ideas or resources.
- Social media may be used as a potential source of information, but an understanding of its limitations is necessary to maintain credibility.
- Software (e.g., Word, Excel) and online tools (e.g. citation generators) are used by researchers to manage and catalog sources and produce reference lists.
- Software and online tools (e.g. Google Drive, Survey Monkey) can be used to survey participants and analyze large data sets.
- The scope and purpose of one's research and the credibility of sources affects the validity of the conclusions.
- Credibility of evidence depends on use of sources and data that are relevant and reliable (current, authoritative).
- Determining the credibility of a source requires considering and evaluating the reputation and credentials of the author, publisher, site owner, and/or sponsor, understanding and evaluating the author's perspective and research methods; and considering how others respond to their work. Scientific articles are often peer-reviewed, meaning the research has been reviewed and accepted by disciplinary experts.
- When gathering data on individual's behaviors, attitudes, and preferences, the accuracy and validity of such data depends on the honesty, memory, and reliability of the respondents and/or observers as well as the design of the data collection instrument.
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- Descriptive or inferential statistics can be used to display and/or analyze data.

- Data/information may be organized and categorized (or coded) to identify patterns or themes.
- Qualitative and quantitative data/information may be combined to triangulate and corroborate trends, patterns, correlations, and/or themes.
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- Setbacks are inevitable; scientists/researchers need to focus on the essential goals of the inquiry or project and be prepared to try alternate approaches to achieve those goals.
- Experts in the field may provide guidance and/or discipline-specific knowledge or perspective. Scientists must learn how to seek advice while maintaining self-sufficiency.
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Competencies:

- Identifying and contextualizing a problem or issue.
- Posing complex questions and seeking out answers that reflect multiple, divergent, or contradictory perspectives.
- Identifying a topic of inquiry.
- Articulating the purpose and significance of the scholarly inquiry.
- Developing and revising a focused research question/project goal.
- Retrieving, questioning, organizing, and using prior knowledge about a topic.
- Accessing and managing information using effective strategies.
- Identifying the information needed and selecting appropriate strategies to find or collect it.
- Designing, planning, and implementing a scientific inquiry
- Demonstrating perseverance through setting goals, managing time, and working independently on a long-term project.
- Employing ethical research practices.

Big Idea #2: Synthesize Ideas

Once enough information is gathered and evaluated, students synthesize their accumulated knowledge, emerging ideas, and perspectives to form conclusions of their own. Students must consider other points of view but also analyze material to develop their own perspectives and scholarly works. The goal is for students to think critically about the information and then add to, not simply repeat, the ideas of others. In this way, students establish a unique, creative voice within the larger conversation.

Essential Questions:

- How do I connect and analyze the evidence in order to develop an argument and support a conclusion?
- Are there other conclusions I should consider?
- How does my work emerge from my perspective?
- How do I account for my biases and assumptions?
- What is the most appropriate way to use other's work to support my argument?
- How do I guarrantee that the conclusions I form are my own?

Concepts:

- Effective arguments use reason and evidence to convey a perspective or point of view stated in a thesis and/or conclusion.
- Effective arguments are supported by connected claims, reasons, and evidence.
- Effective arguments increase credibility and decrease overgeneralization and oversimplification by placing limits on claims.
- Effective arguments may acknowledge and respond to contradictory arguments using concession, refutation, and/or rebuttal.
- Effective arguments use a clear and logical path of reasoning to guide the reader to a conclusion.
- The logic of an argument may be deductive (claim followed by evidence) or inductive (evidence followed by a conclusion).
- A line of reasoning is organized based on the argument's purpose.
- Claims and supporting evidence are arranged to convey reasoning and relationship.
- The same argument may be organized, arranged, or supported in multiple ways, depending on the audience and the context.
- Whether developing an argument or conceptualizing an idea, a researcher must thoughtfully choose and implement a process aligned with the project goal.
- Each discipline has its own conventions and manners of communicating.
- Researchers apply discipline-specific terminology in their analysis.
- Different disciplines methods for learning and evaluating information may be discovered through engaging with discipline-specific foundational texts and works.
- Disciplines may be either broadly or narrowly defined.
- Different disciplines may be combined to provide new perspectives.
- Evidence can be from print sources, experts, or data collected in surveys and experiments.
- Evidence is used to support the claims and reasoning of an argument. Compelling evidence is sufficient, accurate, relevant, current, and credible.
- Evidence is chosen to align an argument with authority, define a concept, illustrate a process, clarify a statement, set a mood, provide an example, and/or to qualify a point.

- Commentary connects the chosen evidence to the claim through interpretation or inference, identifying patterns, describing trends, and/or explaining relationships.
- Plagiarism is a serious offense that occurs when a person presents another's ideas or words as his or her own. Plagiarism may be avoided by acknowledging sources thoroughly and accurately.
- Source material should be introduced, integrated, or embedded into the text of an argument.
- Quoted and paraphrased material must be properly attributed, credited, and cited following a style manual.
- Academic disciplines use specific style guides for citing and attributing sources (e.g., APA, MLA, Chicago, AMA).
- Innovative solutions and arguments identify and challenge assumptions, acknowledge the importance of content, imagine and explore alternatives, and engage in reflective skepticism.
- When making choices and proposing solutions, the advantages and disadvantages of the options should be weighed against the goal.

Competencies:

- Formulating a complex and well-reasoned argument.
- Selecting and consistently applying an appropriate disciplinary approach to form a scientific argument.
- Interpreting, using, and synthesizing qualitative and/or quantitative data from various sources (e.g. primary, secondary, print, non-print) to develop and support an argument.
- Providing insightful and cogent commentary that links evidence with claims.
- Attributing knowledge and ideas accurately and ethically using an appropriate citation style.
- Extending an idea, question, process, or product to innovate or create new understandings.
- Offering resolutions, conclusions, and/or solutions based on evidence as well as considering consequences and implications.

Big Idea #3: Communicate

Collaboration, communication, and reflection are skills that provide opportunities for students to develop their learning. When collaborating, students draw upon their own strengths and the strengths of a team of peers, mentors, and teachers to achieve their best possible work. Students should engage in peer review and personal revision to refine and tailor their arguments. An argument is effectively communicated when its purpose is clear, it is tailored to a specific audience and context, and it is conveyed through a medium appropriate and appealing to the intended audience. Adhering to standard language conventions and engaging delivery techniques establishes a writer's or speaker's credibility with his or her audience. Whether working alone or in a group, students reflect on their work and learning processes, which can lead to personal growth as well as even more effective inquiry, learning, and collaboration.

Essential Questions:

- How can I best appeal to and engage my audience?
- What is the best medium or genre through which to reach my audience?

- How might I adapt my written and oral presentations for different audiences and situations?
- How might my communication choices reflect my credibility with my audience?
- Which revision strategies are most appropriate to developing and refining my project at different stages?
- How do I provide feedback that is valuable to others?
- How do I act upon feedback that I have received?
- How can I benefit from reflecting on my own work?

Concepts:

- Research results in conclusions that can be presented in different formats and that typically have the following elements:
    - Introduction – provides background and contextualizes the research question/project/goal, reviews previous work in the field, and identifies the gap in the current field of knowledge to be addressed
    - Hypothesis – specific and testable statement of the main idea of the research question/project/goal
    - Method – explains and provides justification for the chosen method, process, or approach
    - Results - presents the results, product, evidence, or findings
    - Analysis – interprets the significance of the results, product, or findings; explores the connections to the original research question/project/goal; and discusses the implications and limitations of the research
    - Conclusion – summarizes the findings, reflects on the process, and discusses how the project could impact the field
    - References – provides a complete list of sources cited and consulted in the appropriate disciplinary style
- A writer expresses tone or attitude about a topic through word choice, sentence structure, and imagery.
- Effective sentences create variety, emphasis, and interest through structure, agreement of elements, placement of modifiers, and consistency of tense.
- Precision in word choice reduces confusion, wordiness, and redundancy.
- Spelling and grammar errors detract from credibility.
- Effective organizational and design elements (e.g., headings, layout, illustrations, quotes, captions, lists) may aid in audience engagement and understanding by calling attention to important information.
- Data and other information can be presented graphically (e.g., infographics, graphs, tables, models) to aid audience understanding and interpretation.
- Effective communication requires choosing appropriate media according to context, purpose, and audience.
- Arguments can be adapted by strategically selecting and emphasizing information considering audience, medium, and purpose.
- Researchers should articulate their choices and content in a language that is not discipline-specific to communicate effectively to non-experts and/or people outside the discipline.
- Speakers vary elements of delivery to emphasize information, convey tone, and engage their audience.

- Researchers produce and present their completed work after multiple revisions and rehearsals.
- Researchers effectively articulate the rationale for inquiry choices in relation to their completed work.
- Researchers engage thoughtfully with their audiences' critiques and questions.
- Reflection is an ongoing and recursive process in inquiry, often leading to changes in understanding.
- Learning requires practice through an iterative process of thinking/rethinking, vision/revision, and writing/rewriting.
- Researchers are mindful of the rationale behind the chosen method for data collection, information gathering, analysis, production, and presentation.
- Researchers reflect on how the inquiry process helped them deepen their understanding, make important connections, and develop self-direction.
- Reflective researchers explore potential future directions for their inquiries and the development of their own scholarship or bodies of work.
- Reflective researchers acknowledge how their inquiry processes and resulting works can be transformational for their own and other's understanding as well as for their personal identities as scholars.
- Peer review should be based on guidelines and defined criteria appropriate to the work.
- Peer review is an effective way for researchers to strengthen their own work.

Competencies:

- Planning, producing, and presenting a cohesive academic paper, considering audience, context, and purpose.
- Adhering to established conventions of grammar, usage, style, and mechanics.
- Communicating information using effective techniques of design.
- Adapting an argument for context, purpose, and/or audience.
- Engaging an audience by employing effective techniques of delivery or performance.
- Defending inquiry choices and final product with clarity, consistency, and conviction.
- Reflecting on and revising their own writing, thinking, and creative process.
- Reflecting on the larger significance of engaging in the overall inquiry process and producing a completed scholarly work.
- Engaging in peer review to provide constructive responses to one another's work, appropriate to the stage of a project's development.
- Engaging in peer review to receive and consider responses to their work.

Big Idea #4: Technology Use

Technology is created, used, and modified by humans.

Essential Questions:

- What knowledge and skills are essential for humans to make sound decisions about creating, using, and modifying technologies?

Concepts:

- Decisions about the use of products and systems can result in known and unexpected consequences.

- The study of the impacts of technological systems enables us to plan and direct technological developments.
- The goal of technology is to improve the human condition by maximizing positive impacts and minimizing negative one.
- While science is the study of the natural world, technology is the study of the human designed world.
- Science and technology are inextricably connected and are driven by human decision making.

Competencies:

- Analyze decisions related to the use of technology, predict consequences and compare with the results of the designed system
- Design, build, and test/evaluate a technological system to analyze its positive and negative consequences and impacts on individuals, societal institutions and our environment.
- Apply scientific and mathematical principles to an advanced engineering design problem then build and assess it.
- Maintain an engineering design journal that documents the complementary roles of science and math concepts in the engineering design process.
- Design, produce and transmit a message through a technological channel then analyze the effectiveness in terms of the initial goals.

Big Idea #5: Technology Literacy

Technological literacy is the ability to use, assess and manage technology around us.

Essential Questions:

- What is the importance of technological literacy?

Concepts:

- Technology and society mutually impact each other.
- Technological literacy is the ability to understand, use, assess, design, and produce technology (i.e. Invention & Innovation).
- Technological literacy is required for all citizens in a democratic society for shared decision-making.
- Technological literacy is necessary for a productive 21st century skilled workforce.
- Technological literacy is a lifetime endeavor.
- People select, create, and use science and technology and are limited by constraints (e.g. social and physical).

Competencies:

- Design, produce, test and analyze a technological solution that has desirable impacts on a culture that improves local, regional, or global economic conditions.
- Use current technological systems efficiently, identify undesirable results, then design, produce, test and utilize engineering analysis to optimize solutions.
- Demonstrate, model and communicate how societies depend on technology to use information, physical and bio-related systems to create desirable solutions to human needs and wants.

- Design, produce, test and analyze systems that use technological resources for the purpose of improving on existing technologies to impact individual lives, societies, our world, and the environment.
- Debate current technological issues and opportunities using informed decision making in a democratic society.
- Identify how specific technological inventions and innovations are constrained by the natural and legislative world in various societies.

Big Idea #6: Technology Developments

A technological world requires that humans develop capabilities to solve technological challenges and improve products for the way we live.

Essential Questions:

- How have technological developments impacted devices, processes, and systems to fulfill human wants and needs?

Concepts:

- The abilities required in a technological world include diagnosing, troubleshooting, analyzing and maintaining systems.
- Innovation is the process of modifying an existing product, process, or system to improve it.
- Invention is a process of turning ideas and imagination into new products, processes, or systems.
- Safety is a preeminent concern for all technological development and use.
- In a technological world, inventions and innovations must be carefully assessed by individuals and society as a whole.

Competencies:

- Use and maintain technological products and systems and describe their functions, advantages/disadvantages and hazards/benefits.
- Through a structured engineering design process, select an existing product and design, build, and assess an improved version.
- Utilize a structured innovation process to create a new product, process or system.
- Use tools and machines safely and explain the common and particular hazards of specific technological devices.
- Assess the origins and importance of specific technological inventions and innovations and predict future impacts of proposed technologies.
- Design a message, select a communication channel, produce and disseminate it and analyze its effectiveness.

Big Idea #7: Technology Characteristics

Each area of technology has a set of characteristics that separates it from others; however, many areas overlap in order to meet human needs and wants.

Essential Questions:

- How do various areas of technology influence the economy, the environment, society, and political decisions?

Concepts:

- Manufacturing is the process of turning raw materials into useful products.
- Construction is the process of turning raw materials into useful structures.
- Communication is the process of composing, sending, and receiving messages through technology.
- Transportation is the process of safely and efficiently moving people and products.
- Bio-related technologies are the processes of using biological organisms to make or modify products.
- Energy and power technologies are the processes of converting energy sources into useful power.

Competencies:

- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, manufacture, test, and analyze products that meet human needs and wants.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, construct, test, and analyze structures that meet human needs and wants.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, communicate, test, and analyze messages to meet human needs and wants.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, test, and analyze systems to transport people and products.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, test, and analyze bio-related products and systems to meet human needs and wants.

(There may be several Big Ideas and associated Essential Questions, Concepts, and Competencies within a unit.)

Curriculum Plan

Unit 3: Data Analysis and Conclusion

Time Range in Days: 45 days

Standard(s):

- Pennsylvania Academic Standards for Science and Technology and Engineering Education
- Pennsylvania Core Standards for Reading in Science and Technical Subjects
- Pennsylvania Core Standards for Writing in Science and Technical Subjects
- Pennsylvania Core Standards for Mathematics

Standards Addressed:

- 3.1.12.A9
- 3.4.12.C2
- 3.4.12.C3
- 3.4.12.D2
- 3.4.12.E6
- CC.3.5.11-12.A
- CC.3.5.11-12.B
- CC.3.5.11-12.C
- CC.3.5.11-12.D
- CC.3.5.11-12.G
- CC.3.5.11-12.H
- CC.3.5.11-12.I
- CC.3.5.11-12.J
- CC.3.6.11-12.A
- CC.3.6.11-12.B
- CC.3.6.11-12.C
- CC.3.6.11-12.D
- CC.3.6.11-12.E
- CC.3.6.11-12.F
- CC.3.6.11-12.G
- CC.3.6.11-12.H
- CC.3.6.11-12.I

(Number Only- See Appendix for Description)

Anchor(s):

- S11.A.1.1
- S11.A.1.2
- S11.A.1.3
- S11.A.2.1
- S11.A.2.2
- S11.A.3.1
- S11.A.3.2
- S11.A.3.3
- CC.2.3.HS.A.13
- CC.2.4.HS.B.2
- CC.2.4.HS.B.3
- CC.2.4.HS.B.5

(As Applicable)

Overview:

- Data collection
- Data analysis
- Conclusion based on data
- Problem solving
- Notebook writing
- Technical paper writing

Focus Question(s):

- What data am I collecting?
- How will I analyze that data?
- What conclusions do the data support?

Goals:

- Data collection
- Data analysis
- Conclusion
- Technical paper
- Laboratory notebook

Objectives:

- Collect data (DOK Level 2)
- Analyze (DOK Level 4)
- Create valid conclusion supported by data (DOK Level 4)
- Summarize daily project work in laboratory notebook (DOK Level 2)
- Revise technical paper describing project (DOK Level 4)

Core Activities and Corresponding Instructional Methods:

- Solve problems that arise when experiments are run
  - Discussion
  - Questioning
  - Surveying existing research
  - Independent reading
  - Laboratory notebook writing
  - Laboratory experiments
  - Analyzing experimental results
  - Drawing conclusions from experimental results
- Redesign experiment to incorporate changes made to overcome problems
  - Discussion
  - Questioning
  - Surveying existing research
  - Independent reading
  - Laboratory notebook writing
  - Laboratory experiments
  - Analyzing experimental results
  - Drawing conclusions from experimental results
  - Scientific paper writing and rewriting
- Collect experimental data
  - Laboratory notebook writing
  - Laboratory experiments
  - Analyzing experimental results
  - Presenting experimental results
- Analyze experimental data using statistics and mathematics
  - Discussion
  - Questioning
  - Laboratory notebook writing
  - Laboratory experiments
  - Analyzing experimental results
  - Drawing conclusions from experimental results

  - Scientific paper writing and rewriting
- Draw scientifically valid conclusions from statistical tests of experimental data
  - Discussion
  - Questioning
  - Laboratory notebook writing
  - Laboratory experiments
  - Analyzing experimental results
  - Drawing conclusions from experimental results
  - Presenting experimental results
- Write a technical paper describing project
  - Discussion
  - Questioning
  - Surveying existing research
  - Independent reading
  - Scientific paper writing and rewriting
  - Peer reviewing of other student's papers
- Summarize daily project work in laboratory notebook
  - Discussion
  - Questioning
  - Daily journal writing

Assessments:

Diagnostic:

- Daily progress reports written in laboratory notebooks
- Writing/rewriting technical paper

Formative:

- Suitable idea for independent research project investigation
- Design of scientific experiment investigating project idea
- Written drafts of an APA style scientific paper describing experiment
- Mathematical/Statistical analysis of experimental data
- Practice delivery of presentation summarizing scientific paper

Summative:

- Final draft of scientific paper describing completed independent research project
- Final draft of presentation summarizing scientific paper describing completed independent research project

Extensions:

- Biology, chemistry, physics articles from scientific journals
- Writing for science textbooks
- Statistics textbooks

Correctives:

- Science department faculty supervision
- Research scientist/consulting expert mentoring

Materials and Resources:

- Science department
  - laboratory equipment
  - Computers
  - Sensors
  - Interface equipment
- Google Drive
- American Psychological Association. (July 15, 2009). *Publication Manual of the American Psychological Association*, 6th edition. Washington, DC: American Psychological Association
- Freedman, R., Pisani, R., & Purves, R. (1998). *Statistics* (3rd ed.). New York: W. W. Norton & Company
- Moore, D. S. (1995). The Basic Practice of Statistics. New York: W. H. Freeman and Company
- Pechenik, J. A. (1997). *A Short Guide to Writing About Biology*. New York: Addison-Wesley
- Tufte, E. R. (1990). *Envisioning Information*. Chesire, CT: Graphics Press
- Tufte, E. R. (1983). *The Visual Display of Quantitative Information*. Chesire, CT: Graphics Press
- Tufte, E. R. (1997). *Visual Explanations*. Chesire, CT: Graphics Press
- *Technology Review*. Cambridge, MA: Massachusetts Institute of Technology

UNIT 4: Communicate Project

Big Idea #1: Communicate

Collaboration, communication, and reflection are skills that provide opportunities for students to develop their learning. When collaborating, students draw upon their own strengths and the strengths of a team of peers, mentors, and teachers to achieve their best possible work. Students should engage in peer review and personal revision to refine and tailor their arguments. An argument is effectively communicated when its purpose is clear, it is tailored to a specific audience and context, and it is conveyed through a medium appropriate and appealing to the intended audience. Adhering to standard language conventions and engaging delivery techniques establishes a writer's or speaker's credibility with his or her audience. Whether working alone or in a group, students reflect on their work and learning processes, which can lead to personal growth as well as even more effective inquiry, learning, and collaboration.

Essential Questions:

- How can I best appeal to and engage my audience?
- What is the best medium or genre through which to reach my audience?
- How might I adapt my written and oral presentations for different audiences and situations?
- How might my communication choices reflect my credibility with my audience?
- Which revision strategies are most appropriate to developing and refining my project at different stages?
- How do I provide feedback that is valuable to others?
- How do I act upon feedback that I have received?
- How can I benefit from reflecting on my own work?

Concepts:

- Research results in conclusions that can be presented in different formats and that typically have the following elements:
    - Introduction – provides background and contextualizes the research question/project/goal, reviews previous work in the field, and identifies the gap in the current field of knowledge to be addressed
    - Hypothesis – specific and testable statement of the main idea of the research question/project/goal
    - Method – explains and provides justification for the chosen method, process, or approach
    - Results - presents the results, product, evidence, or findings
    - Analysis – interprets the significance of the results, product, or findings; explores the connections to the original research question/project/goal; and discusses the implications and limitations of the research
    - Conclusion – summarizes the findings, reflects on the process, and discusses how the project could impact the field
    - References – provides a complete list of sources cited and consulted in the appropriate disciplinary style
- A writer expresses tone or attitude about a topic through word choice, sentence structure, and imagery.

- Effective sentences create variety, emphasis, and interest through structure, agreement of elements, placement of modifiers, and consistency of tense.
- Precision in word choice reduces confusion, wordiness, and redundancy.
- Spelling and grammar errors detract from credibility.
- Effective organizational and design elements (e.g., headings, layout, illustrations, quotes, captions, lists) may aid in audience engagement and understanding by calling attention to important information.
- Data and other information can be presented graphically (e.g., infographics, graphs, tables, models) to aid audience understanding and interpretation.
- Effective communication requires choosing appropriate media according to context, purpose, and audience.
- Arguments can be adapted by strategically selecting and emphasizing information considering audience, medium, and purpose.
- Researchers should articulate their choices and content in a language that is not discipline-specific to communicate effectively to non-experts and/or people outside the discipline.
- Speakers vary elements of delivery to emphasize information, convey tone, and engage their audience.
- Researchers produce and present their completed work after multiple revisions and rehearsals.
- Researchers effectively articulate the rationale for inquiry choices in relation to their completed work.
- Researchers engage thoughtfully with their audiences' critiques and questions.
- Reflection is an ongoing and recursive process in inquiry, often leading to changes in understanding.
- Learning requires practice through an iterative process of thinking/rethinking, vision/revision, and writing/rewriting.
- Researchers are mindful of the rationale behind the chosen method for data collection, information gathering, analysis, production, and presentation.
- Researchers reflect on how the inquiry process helped them deepen their understanding, make important connections, and develop self-direction.
- Reflective researchers explore potential future directions for their inquiries and the development of their own scholarship or bodies of work.
- Reflective researchers acknowledge how their inquiry processes and resulting works can be transformational for their own and other's understanding as well as for their personal identities as scholars.
- Peer review should be based on guidelines and defined criteria appropriate to the work.
- Peer review is an effective way for researchers to strengthen their own work.

Competencies:

- Planning, producing, and presenting a cohesive academic paper, considering audience, context, and purpose.
- Adhering to established conventions of grammar, usage, style, and mechanics.
- Communicating information using effective techniques of design.
- Adapting an argument for context, purpose, and/or audience.
- Engaging an audience by employing effective techniques of delivery or performance.
- Defending inquiry choices and final product with clarity, consistency, and conviction.

- Reflecting on and revising their own writing, thinking, and creative process.
- Reflecting on the larger significance of engaging in the overall inquiry process and producing a completed scholarly work.
- Engaging in peer review to provide constructive responses to one another's work, appropriate to the stage of a project's development.
- Engaging in peer review to receive and consider responses to their work.

Big Idea #2: Technology Use

Technology is created, used, and modified by humans.

Essential Questions:

- What knowledge and skills are essential for humans to make sound decisions about creating, using, and modifying technologies?

Concepts:

- Decisions about the use of products and systems can result in known and unexpected consequences.
- The study of the impacts of technological systems enables us to plan and direct technological developments.
- The goal of technology is to improve the human condition by maximizing positive impacts and minimizing negative one.
- While science is the study of the natural world, technology is the study of the human designed world.
- Science and technology are inextricably connected and are driven by human decision making.

Competencies:

- Analyze decisions related to the use of technology, predict consequences and compare with the results of the designed system
- Design, build, and test/evaluate a technological system to analyze its positive and negative consequences and impacts on individuals, societal institutions and our environment.
- Apply scientific and mathematical principles to an advanced engineering design problem then build and assess it.
- Maintain an engineering design journal that documents the complementary roles of science and math concepts in the engineering design process.
- Design, produce and transmit a message through a technological channel then analyze the effectiveness in terms of the initial goals.

Big Idea #3: Technology Literacy

Technological literacy is the ability to use, assess and manage technology around us.

Essential Questions:

- What is the importance of technological literacy?

Concepts:

- Technology and society mutually impact each other.
- Technological literacy is the ability to understand, use, assess, design, and produce technology (i.e. Invention & Innovation).
- Technological literacy is required for all citizens in a democratic society for shared decision-making.
- Technological literacy is necessary for a productive 21st century skilled workforce.
- Technological literacy is a lifetime endeavor.
- People select, create, and use science and technology and are limited by constraints (e.g. social and physical).

Competencies:

- Design, produce, test and analyze a technological solution that has desirable impacts on a culture that improves local, regional, or global economic conditions.
- Use current technological systems efficiently, identify undesirable results, then design, produce, test and utilize engineering analysis to optimize solutions.
- Demonstrate, model and communicate how societies depend on technology to use information, physical and bio-related systems to create desirable solutions to human needs and wants.
- Design, produce, test and analyze systems that use technological resources for the purpose of improving on existing technologies to impact individual lives, societies, our world, and the environment.
- Debate current technological issues and opportunities using informed decision making in a democratic society.
- Identify how specific technological inventions and innovations are constrained by the natural and legislative world in various societies.

Big Idea #4: Technology Design

Technological design is a creative process that anyone can do which may result in new inventions and innovations.

Essential Questions:

- How would you explain and apply technological design and problem solving methods in the development of inventions and innovations?

Concepts:

- Technological design & problem solving utilizes a series of steps that take place in a well-defined sequence.
- Technological design & problem solving transforms an idea into a final product or system.

- Technological design & problem solving requires the application of hands-on abilities such as sketching, prototyping, and fabricating.
- Technological design & problem solving includes both formative and summative analysis.
- Technological design & problem solving requires the ability to clearly communicate engineered solutions.

Competencies:

- Employ engineering design and problem solving skills to solve complex technological challenges.
- Transform ideas into technological products and/or systems using a focused engineering design process.
- Utilize computer-aided engineering design software to solve advanced, real-world technological problems.
- Document progress through the engineering design process using a journal that synthesizes the process and results.
- Evaluate the effectiveness of engineered solutions through written, spoken, mathematical, and graphical means.

Big Idea #5: Technology Developments

A technological world requires that humans develop capabilities to solve technological challenges and improve products for the way we live.

Essential Questions:

- How have technological developments impacted devices, processes, and systems to fulfill human wants and needs?

Concepts:

- The abilities required in a technological world include diagnosing, troubleshooting, analyzing and maintaining systems.
- Innovation is the process of modifying an existing product, process, or system to improve it.
- Invention is a process of turning ideas and imagination into new products, processes, or systems.
- Safety is a preeminent concern for all technological development and use.
- In a technological world, inventions and innovations must be carefully assessed by individuals and society as a whole.

Competencies:

- Use and maintain technological products and systems and describe their functions, advantages/disadvantages and hazards/benefits.
- Through a structured engineering design process, select an existing product and design, build, and assess an improved version.
- Utilize a structured innovation process to create a new product, process or system.
- Use tools and machines safely and explain the common and particular hazards of specific technological devices.

- Assess the origins and importance of specific technological inventions and innovations and predict future impacts of proposed technologies.
- Design a message, select a communication channel, produce and disseminate it and analyze its effectiveness.

Big Idea #6: Technology Characteristics

Each area of technology has a set of characteristics that separates it from others; however, many areas overlap in order to meet human needs and wants.

Essential Questions:

- How do various areas of technology influence the economy, the environment, society, and political decisions?

Concepts:

- Manufacturing is the process of turning raw materials into useful products.
- Construction is the process of turning raw materials into useful structures.
- Communication is the process of composing, sending, and receiving messages through technology.
- Transportation is the process of safely and efficiently moving people and products.
- Bio-related technologies are the processes of using biological organisms to make or modify products.
- Energy and power technologies are the processes of converting energy sources into useful power.

Competencies:

- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, manufacture, test, and analyze products that meet human needs and wants.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, construct, test, and analyze structures that meet human needs and wants.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, communicate, test, and analyze messages to meet human needs and wants.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, test, and analyze systems to transport people and products.
- Select and safely and effectively use appropriate tools, materials, and processes to design, engineer, test, and analyze bio-related products and systems to meet human needs and wants.

(There may be several Big Ideas and associated Essential Questions, Concepts, and Competencies within a unit.)**.**

Curriculum Plan

Unit 4: Communicate Project **Time Range in Days: 45 days**

Standard(s):

- Pennsylvania Academic Standards for Science and Technology and Engineering Education
- Pennsylvania Core Standards for Reading in Science and Technical Subjects
- Pennsylvania Core Standards for Writing in Science and Technical Subjects
- Pennsylvania Core Standards for Mathematics

Standards Addressed:

- 3.1.12.A9
- 3.4.12.C2
- 3.4.12.C3
- 3.4.12.D2
- 3.4.12.E6
- CC.3.5.11-12.A
- CC.3.5.11-12.B
- CC.3.5.11-12.C
- CC.3.5.11-12.D
- CC.3.5.11-12.G
- CC.3.5.11-12.H
- CC.3.5.11-12.I
- CC.3.5.11-12.J
- CC.3.6.11-12.A
- CC.3.6.11-12.B
- CC.3.6.11-12.C
- CC.3.6.11-12.D
- CC.3.6.11-12.E
- CC.3.6.11-12.F
- CC.3.6.11-12.G
- CC.3.6.11-12.H
- CC.3.6.11-12.I

(Number Only- See Appendix for Description)

Anchor(s):

- S11.A.1.1
- S11.A.1.2
- S11.A.1.3
- S11.A.2.1
- S11.A.2.2
- S11.A.3.1
- S11.A.3.2
- S11.A.3.3
- CC.2.3.HS.A.13
- CC.2.4.HS.B.2
- CC.2.4.HS.B.3
- CC.2.4.HS.B.5

(As Applicable)

Overview:

- Problem solving
- Notebook writing
- Technical paper writing
- Scientific presentation creating
- Scientific presentation delivering

Focus Question(s):

- What did I learn from my project?
- How can I summarize what I did and what I learned?

Goals:

- Laboratory notebook
- Technical paper
- Scientific presentation

Objectives:

- Summarize daily project work in laboratory notebook (DOK Level 2)
- Revise technical paper describing project (DOK Level 4)
- Create scientific presentation describing project (DOK Level 4)

Core Activities and Corresponding Instructional Methods:

- Summarize daily project work in laboratory notebook
  - Discussion
  - Questioning
  - Daily journal writing
- Write a technical paper describing project
  - Discussion
  - Questioning
  - Surveying existing research
  - Independent reading
  - Scientific paper writing and rewriting
  - Peer reviewing of other student's papers
- Create and deliver a presentation summarizing technical paper
  - Discussion
  - Questioning
  - Scientific paper writing and rewriting
  - Peer reviewing of other student's presentations
  - Presenting experimental results

Assessments:

Diagnostic:

- Daily progress reports written in laboratory notebooks
- Writing/rewriting technical paper

Formative:

- Suitable idea for independent research project investigation
- Design of scientific experiment investigating project idea
- Written drafts of an APA style scientific paper describing experiment
- Mathematical/Statistical analysis of experimental data
- Practice delivery of presentation summarizing scientific paper

Summative:

- Final draft of scientific paper describing completed independent research project
- Final draft of presentation summarizing scientific paper describing completed independent research project

Extensions:

- Biology, chemistry, physics articles from scientific journals
- Writing for science textbooks
- Statistics textbooks

Correctives:

- Science department faculty supervision
- Research scientist/consulting expert mentoring

Materials and Resources:

- Science department
  - laboratory equipment
  - Computers
  - Sensors
  - Interface equipment
- Google Drive
- American Psychological Association. (July 15, 2009). *Publication Manual of the American Psychological Association*, 6th edition. Washington, DC: American Psychological Association
- Freedman, R., Pisani, R., & Purves, R. (1998). *Statistics* (3rd ed.). New York: W. W. Norton & Company
- Moore, D. S. (1995). The Basic Practice of Statistics. New York: W. H. Freeman and Company
- Pechenik, J. A. (1997). *A Short Guide to Writing About Biology*. New York: Addison-Wesley
- Tufte, E. R. (1990). *Envisioning Information*. Chesire, CT: Graphics Press
- Tufte, E. R. (1983). *The Visual Display of Quantitative Information*. Chesire, CT: Graphics Press
- Tufte, E. R. (1997). *Visual Explanations*. Chesire, CT: Graphics Press
- *Technology Review*. Cambridge, MA: Massachusetts Institute of Technology

Primary Textbook(s) Used for this Course of Instruction

There is no textbook for this course

Name of Textbook:

- N/A

Textbook ISBN #:

- N/A

Textbook Publisher &Year of Publication:

- N/A

Curriculum Textbook is utilized in (title of course):

- N/A

Please complete one sheet for each primary textbook.

Appendix

Curriculum Resources:

- Academic Standards for Science and Technology and Engineering Education (Secondary Standards – Biology, Chemistry, and Physics). (2010, January 29). Retrieved December 17, 2015.
- Academic Standards for Reading In Science and Technical Subjects (Grades 6 – 12). (2014, March 01). Retrieved December 17, 2015.
- Academic Standards for Writing In Science and Technical Subjects (Grades 6 – 12). (2014, March 01). Retrieved December 17, 2015.
- Academic Standards for Mathematics (Grades Pre K – High School). (2014, March 01). Retrieved December 17, 2015.
- Science Grade 11 Assessment Anchors and Eligible Content (Science Grade 11). (2007). Retrieved July 24, 2016.
- Grade 11 Mathematics Alternate Eligible Content. (2015, November 19). Retrieved July 24, 2016.
- AP Research Course and Exam Description. (2015). Retrieved December 17, 2015

Pennsylvania Academic Standards for Science and Technology and Engineering Education

- 3.1.12.A9. Science as Inquiry
  - Examine the status of existing theories
  - Evaluate experimental information for relevance and adherence to science processes
  - Judge that conclusions are consistent and logical with experimental conditions
  - Interpret results of experimental research to predict new information, propose additional investigable questions, or advance a solution
  - Communicate and defend a scientific argument
- 3.4.12.C2. Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly
- 3.4.12.C3. Apply the concept that many technological problems require a multi-disciplinary approach
- 3.4.12.D2. Verify that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly
- 3.4.12.E6. Compare and contrast the importance of science, technology, engineering and math (STEM) as it pertains to the manufactured world

Pennsylvania Core Standards for Reading in Science and Technical Subjects

- CC.3.5.11-12.A. Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account
- CC.3.5.11-12.B. Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms
- CC.3.5.11-12.C. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text
- CC.3.5.11-12.D. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11–12 texts and topics

- CC.3.5.11-12.G. Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem
- CC.3.5.11-12.H. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information
- CC.3.5.11-12.I. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible
- CC.3.5.11-12.J. By the end of grade 12, read and comprehend science/technical texts in the grades 11–12 text complexity band independently and proficiently

Pennsylvania Core Standards for Writing in Science and Technical Subjects

- CC.3.6.11-12.A. Write arguments focused on discipline-specific content
  - 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
  - Develop claim(s) and counterclaims fairly 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
  - Use words, phrases, and clauses as well as varied syntax 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
  - Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing
  - Provide a concluding statement or section that follows
- CC.3.6.11-12.B. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes
  - Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension
  - Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic
  - Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts
  - Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers
  - Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).
- CC.3.6.11-12.C. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience

- CC.3.6.11-12.D. Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience
- CC.3.6.11-12.E. Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information
- CC.3.6.11-12.F. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation
- CC.3.6.11-12.G. Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation
- CC.3.6.11-12.H. Draw evidence from informational texts to support analysis, reflection, and research
- CC.3.6.11-12.I. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences

Science Grade 11 Assessment Anchors and Eligible Content

- S11.A.1.1 Analyze and explain the nature of science in the search for understanding the natural world and its connection to technological systems.
- S11.A.1.2 Identify and analyze the scientific or technological challenges of societal issues; propose possible solutions and discuss implications.
- S11.A.1.3 Describe and interpret patterns of change in natural and human-made systems.
- S11.A.2.1 Apply knowledge of scientific investigation or technological design to
- develop or critique aspects of the experimental or design process.
- S11.A.2.2 Evaluate appropriate technologies for a specific purpose, or describe the
- information the instrument can provide.
- S11.A.3.1 Analyze the parts of a simple system, their roles, and their relationships to the system as a whole.
- S11.A.3.2 Compare observations of the real world to observations of a constructed model.
- S11.A.3.3 Compare and analyze repeated processes or recurring elements in patterns.

Pennsylvania Core Standards for Mathematics

- CC.2.3.HS.A.13: Analyze relationships between two-dimensional and three dimensional objects
- CC.2.4.HS.B.2: Summarize, represent, and interpret data on two categorical and quantitative variables
- CC.2.4.HS.B.3: Analyze linear models to make interpretations based on the data
- CC.2.4.HS.B.5: Make inferences and justify conclusions based on sample surveys, experiments, and observational studies

Mathematics Grade 11 PA Alternate Eligible Content

- CC.2.3.HSA13a Match corresponding two-dimensional and three-dimensional representations

- CC.2.4.HSB2a Interpret the means and/or medians of two sets of data
- CC.2.4.HSB3a Identify the relationship between two or more variables in a function
- CC.2.4.HSB5a Draw a conclusion about data presented in a two-way table representing a real-world problem

Checklist to Complete and Submit with Curriculum:

_____ A hard copy of the curriculum using The template entitled "Planned Instruction," available on the district website

_____ Hard copies of all supplemental resources not available electronically

_____ The primary textbook form(s)

_____ The appropriate payment form, in compliance with the maximum curriculum writing hours noted on the first page of this document

_____ A USB/Flash Drive containing a single file that will print the curriculum in its intended sequence from beginning to end and all supplemental resources that are available in electronic format.

Each principal and/or department chair has a schedule of First and Second Readers/Reviewers. Each Reader/Reviewer must sign & date below.

First Reader/Reviewer Printed Name_____

First Reader/Reviewer Signature_____ Date_____

Second Reader/Reviewer Printed Name_____

Second Reader/Reviewer Signature _____ Date_____