K-12 Science and Engineering Practices* Progression Matrix of Elements

For use with *Arizona Science Standards*

Science and Engineering Practices	K–2 Condensed Practices	3–5 Condensed Practices	6–8 Condensed Practices	9–12 Condensed Practices
Asking Questions and Defining Problems A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested. Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify ideas.	Asking questions and defining problems in grades K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested. ▪ Ask questions based on observations of the natural and/or designed world. ▪ Define a simple problem that can be solved through the development of a new or improved object or tool.	Asking questions and defining problems in grades 3–5 builds from grades K–2 experiences and progresses to specifying qualitative relationships. ▪ Identify scientific (testable) and non-scientific (non-testable) questions. ▪ Ask questions based on careful observations of phenomena and information. ▪ Ask questions to clarify ideas or request evidence. ▪ Ask questions that relate one variable to another variable. ▪ Ask questions to clarify the constraints of solutions to a problem. ▪ Use prior knowledge to describe problems that can be solved. ▪ Define a simple design problem that can be solved through the development of an object, tool or process and includes several criteria for success and constraints on materials, time, or cost. ▪ Formulate questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.	Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable models that support explanations of phenomena or solutions to problems. ▪ Ask questions that arise from careful observation of phenomena, models, or unexpected results. ▪ Ask questions to clarify or identify evidence and the premise(s) of an argument. ▪ Ask questions to determine relationships between independent and dependent variables. ▪ Ask questions that challenge the interpretation of a data set. ▪ Ask questions to clarify and refine a model, an explanation, or an engineering problem. ▪ Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. ▪ Formulate a question that can be investigated within the scope of the classroom, school laboratory, or field with available resources and, when appropriate, frame a hypothesis (a possible explanation that predicts a particular and stable outcome) based on a model or theory.	Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design solutions using models and simulations. ▪ Ask questions that arise from careful observation of phenomena, models, theory, or unexpected results. ▪ Ask questions that require relevant empirical evidence to answer. ▪ Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables. ▪ Ask and evaluate questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. ▪ Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations

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Developing and Using Models A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.	Modeling in K–2 builds on prior experiences and progresses to include identifying, using, and developing models that represent concrete events or design solutions. ▪ Distinguish between a model and the actual object, process, and/or events the model represents. ▪ Compare models to identify common features and differences. ▪ Develop and/or use models (i.e., diagrams, drawings, physical replicas, dioramas, dramatizations, or storyboards) that represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed worlds. ▪ Develop a simple model that represents a proposed object or tool.	Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions. ▪ Develop and revise models collaboratively to measure and explain frequent and regular events. ▪ Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. ▪ Use simple models to describe or support explanations for phenomena and test cause and effect relationships or interactions concerning the functioning of a natural or designed system. ▪ Identify limitations of models. ▪ Develop a diagram or simple physical prototype to convey a proposed object, tool or process. ▪ Use a simple model to test cause and effect relationships concerning the functioning of a proposed object, tool or process.	Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems. ▪ Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. ▪ Develop models to describe unobservable mechanisms. ▪ Modify models—based on their limitations—to increase detail or clarity, or to explore what will happen if a component is changed. ▪ Use and develop models of simple systems with uncertain and less predictable factors. ▪ Develop a model that allows for manipulation and testing of a proposed object, tool, process or system. ▪ Evaluate limitations of a model for a proposed object or tool.	Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world. ▪ Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations. ▪ Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system. ▪ Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems. ▪ Design a test of a model to ascertain its reliability. ▪ Develop a complex model that allows for manipulation and testing of a proposed process or system. ▪ Evaluate merits and limitations of two different models of the same proposed tool, process, or system in order to select or revise a model that best fits the evidence or design criteria.

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Planning and Carrying Out Investigations Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions.	Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions. ▪ With guidance, design and conduct investigations in collaboration with peers. ▪ Design and conduct investigations collaboratively. ▪ Evaluate different ways of observing and/or measuring an attribute of interest. ▪ Make direct or indirect observations and/or measurements to collect data, which can be used to make comparisons. ▪ Identify questions and make predictions based on prior experiences. ▪ Make direct or indirect observations and/or measurements of a proposed object or tool or solution to determine if it solves a problem or meets a goal.	Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions. ▪ Design and conduct investigations collaboratively, using fair tests in which variables are controlled and the number of trials considered. ▪ Evaluate appropriate methods and tools for collecting data. ▪ Make observations and/or measurements, collect appropriate data, and identify patterns that provide evidence for an explanation of a phenomenon or test a design solution. ▪ Make measurements of two different models of the same proposed object, tool or process to determine which better meets criteria for success.	Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions. ▪ Conduct an investigation and evaluate and revise the experimental design to ensure that the data generated can meet the goals of the experiment. ▪ Design an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how much data are needed to support their claim. ▪ Evaluate the accuracy of various methods for collecting data. ▪ Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. ▪ Collect data about the performance of a proposed object, tool, process or system under a range of conditions.	Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models. ▪ Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. ▪ Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. ▪ Select appropriate tools to collect, record, analyze, and evaluate data. ▪ Design and conduct investigations and test design solutions in a safe and ethical manner including considerations of environmental, social, and personal impacts. ▪ Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. ▪ Use investigations to gather evidence to support explanations or concepts.

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Analyzing and Interpreting Data Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.	Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations. ▪ Use and share pictures, drawings, and/or writings of observations. ▪ Use observations to describe patterns and/or relationships in the natural and designed worlds in order to answer scientific questions and solve problems. ▪ Make measurements of length to quantify data. ▪ Analyze data from tests of an object or tool to determine if a proposed object or tool functions as intended.	Analyzing data in 3–5 builds on K–2 and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. ▪ Display data in tables and graphs, using digital tools when feasible, to reveal patterns that indicate relationships. ▪ Use data to evaluate claims about cause and effect. ▪ Compare data collected by different groups in order to discuss similarities and differences in their findings. ▪ Use data to evaluate and refine design solutions. ▪ Interpret data to make sense of and explain phenomena, using logical reasoning, mathematics, and/or computation. ▪ Analyze data to refine a problem statement or the design of a proposed object, tool or process.	Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. ▪ Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible. ▪ Construct, analyze, and interpret graphical displays of data to identify linear and nonlinear relationships. ▪ Consider limitations of data analysis (e.g., measurement error), and seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). ▪ Analyze and interpret data in order to determine similarities and differences in findings. ▪ Distinguish between causal and correlational relationships. ▪ Use graphical displays (e.g., maps) of large data sets to identify temporal and spatial relationships. ▪ Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.	Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. ▪ Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. ▪ Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data. ▪ Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. ▪ Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. ▪ Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. ▪ Evaluate the impact of new data on a working explanation of a proposed process or system.

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Using Mathematics and Computational Thinking In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions.	Mathematical and computational thinking at the K–2 level builds on prior experience and progresses to recognizing that mathematics can be used to describe the natural and designed world ▪ Decide when to use qualitative vs. quantitative data. ▪ Use counting and numbers to identify and describe patterns in the natural and designed worlds. ▪ Describe, measure, and compare quantitative attributes of different objects and display the data using simple graphs. ▪ Use quantitative data to compare two alternative solutions to a problem.	Mathematical and computational thinking at the 3–5 level builds on K–2 and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to compare alternative design solutions. ▪ Use mathematical thinking and/or computational outcomes to compare alternative solutions to an engineering problem. ▪ Organize simple data sets to reveal patterns that suggest relationships. ▪ Describe, measure, estimate, and graph quantities such as area, volume, weight, and time to address scientific and engineering questions and problems. ▪ Decide if qualitative or quantitative data is best to determine whether a proposed object or tool meets criteria for success.	Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments. ▪ Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. ▪ Create algorithms (a series of ordered steps) to solve a problem. ▪ Apply concepts of ratio, rate, percent, basic operations, and simple algebra to scientific and engineering questions and problems. ▪ Use mathematical arguments to describe and support scientific conclusions and design solutions. ▪ Use digital tools, mathematical concepts, and arguments to test and compare proposed solutions to an engineering design problem.	Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ▪ Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations. ▪ Apply techniques of algebra and functions to represent and solve scientific and engineering problems. ▪ Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. ▪ Create a simple computational model or simulation of a designed device, process, or system.

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Constructing Explanations and Designing Solutions *The end-products of science are explanations and the end-products of engineering are solutions.* The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.	Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions. ▪ Use information from direct or indirect observations to construct explanations. ▪ Use tools and materials provided to design a device or solution to a specific problem. ▪ Distinguish between opinions and evidence in one's own explanations. ▪ Generate and compare multiple solutions to a problem.	Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions. ▪ Construct explanations of observed quantitative relationships (e.g., the distribution of plants in the back yard). ▪ Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or design a solution to a problem. ▪ Identify the evidence that supports particular points in an explanation. ▪ Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation. ▪ Apply scientific knowledge to solve design problems. ▪ Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the problem.	Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories. ▪ Construct explanations for either qualitative or quantitative relationships between variables. ▪ Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. ▪ Base explanations on evidence obtained from sources (including their own experiments) and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. ▪ Undertake design projects, engaging in the design cycle, to construct and implement a solution that meets specific design criteria and constraints. ▪ Apply scientific knowledge and evidence to explain real-world phenomena, examples, or events. ▪ Construct explanations from models or representations. ▪ Apply scientific knowledge to design, construct, and test a design of an object, tool, process or system. ▪ Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.	Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories. ▪ Make quantitative and qualitative claims regarding the relationship between dependent and independent variables. ▪ Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion. ▪ Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. ▪ Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. ▪ Apply scientific knowledge and evidence to explain phenomena and solve design problems, taking into account possible unanticipated effects. ▪ Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

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Engaging in Argument from Evidence *Argumentation is the process by which explanations and solutions are reached.* In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to identify strengths and weaknesses of claims.	Engaging in argument from evidence in K–2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world. ▪ Identify arguments that are supported by evidence. ▪ Listen actively to others' explanations and arguments and ask questions for clarification. ▪ Make a claim about the effectiveness of an object, tool, or solution that is based on relevant evidence.	Engaging in argument from evidence in 3–5 builds from K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world. ▪ Construct and/or support scientific arguments with evidence, data, and/or a model. ▪ Compare and refine arguments based on the strengths and weaknesses of the evidence presented. ▪ Respectfully provide and receive critiques on scientific arguments with peers by citing relevant evidence and posing specific questions. ▪ Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.	Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world. ▪ Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon or a solution to a problem. ▪ Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. ▪ Respectfully provide and receive critiques on scientific arguments by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. ▪ Compare two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. ▪ Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system, based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints.	Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science. ▪ Critique and evaluate competing arguments, models, and/or design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. ▪ Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. ▪ Construct a counter-argument that is based on data and evidence that challenges another proposed argument. ▪ Make and defend a claim about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence. ▪ Evaluate a claim for a design solution to a real-world problem based on scientific knowledge, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

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Obtaining, Evaluating, and Communicating Information Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to acquire information that is used to evaluate the merit and validity of claims, methods, and designs.	Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information. ▪ Read and comprehend grade-appropriate texts and media to acquire scientific and/or technical information. ▪ Critique and/or communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers. ▪ Record observations, thoughts, and ideas. ▪ Explain how specific images (e.g., a diagram showing how a machine works) contribute to and clarify a text. ▪ Obtain information by using various text features (e.g., headings, tables of contents, glossaries, electronic menus, icons).	Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods. ▪ Compare and/or combine across complex texts and/or other reliable media to acquire appropriate scientific and/or technical information. ▪ Determine the main idea of a scientific text and explain how it is supported by key details; summarize the text. ▪ Combine information in written text with that contained in corresponding tables, diagrams, and/or charts. ▪ Use multiple sources to generate and communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts. ▪ Use models to share findings or solutions in oral and/or written presentations, and/or extended discussions. ▪ Obtain and combine information from books and/or other reliable media about potential solutions to a specific design problem.	Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods. ▪ Communicate scientific information and/or technical information (e.g. about a proposed object, tool, process, system) in different formats (e.g., verbally, graphically, textually, and mathematically). ▪ Gather, read, and communicate information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used. ▪ Read critically using scientific knowledge and reasoning to evaluate data, hypotheses, conclusions that appear in scientific and technical texts in light of competing information or accounts; provide an accurate summary of the text distinct from prior knowledge or opinions. ▪ Critically evaluate whether or not technical information on a device, tool or process is relevant to its suitability to solve a specific design problem.	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. ▪ Critically read scientific literature adapted for classroom use to 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. ▪ Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible. ▪ Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system. ▪ Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

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