INTERSTATE PASSPORT®

Passport Learning Outcomes and Proficiency Criteria
Natural Sciences

PASSPORT LEARNING OUTCOMES

Faculty representatives from participating Passport institutions, along with the Passport State Facilitators and project staff, develop Passport Learning Outcomes (PLOs) for each lower-division general education knowledge and skill area. The Passport Interstate Faculty Team – comprised of faculty members with expertise in the designated area – review, compare, and contrast the sets of learning outcomes submitted by each state and then negotiate to arrive at an agreed-upon set of learning outcomes – the *Passport Learning Outcomes*. Team members vet the draft learning outcomes with faculty and other stakeholders in their states, and through a series of team conference calls, the learning outcomes are refined and finalized for the knowledge or skill area. Institutions that sign the Passport Agreement acknowledge that their lower-division general education learning outcomes map to and are congruent with the Passport Learning Outcomes.

PROFICIENCY CRITERIA

The proficiency criteria describe the EVIDENCE of proficiency with the Passport Learning Outcomes at the transfer level that one might see in a student's behavior, performance or work. These are observable behaviors rather than subjective descriptors such as "appropriate" or "excellent." Specific examples, provided in the Transfer-Level Proficiency Criteria column of the matrix below, are not intended to mandate curriculum or assessment methods, nor do they constitute a comprehensive list of concepts that each student must master. Rather, they serve as guidelines for determining whether a student has reached the desired level of proficiency for the specific learning outcome through a variety of possible methods. The inclusion of many diverse concrete examples is intentional as different courses may address a given feature in distinct ways; for example, a statistics course will address learning outcomes differently than a quantitative reasoning course. Also, a given concrete example may possibly address more than one Passport Learning Outcome. No single course, or Passport student, is expected to demonstrate all of these criteria of transfer-level proficiency.

NATURAL SCIENCES FRAMING LANGUAGE

Proficiency in the natural sciences entails exploration and comprehension of the universe that requires an informed understanding of the scientific method and its scope and an appreciation of the inherent beauty and wonder that one can find in science and its possibilities. It requires the application of the scientific method in conducting research by gathering and subjecting empirical evidence to quantitative analysis. Proficiency also demands understanding that all applicable evidence must be integrated into scientific models of the universe, and that scientific models must evolve. Relationship to institution's Passport Block: this area includes basic proficiency in the knowledge of concept in disciplines such as astronomy, biology, chemistry, geology, physics, and others.

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The Nature of Science	explain the following attributes of science: a. Science is based on the assumption that reality exists, operates by consistent principles, and that the rules are understandable by critical analysis.	1. Students can identify examples of scientific thinking a. Students explain on an exam or assignment why the assumption that the universe operates by consistent principles and that these rules are understandable by critical analysis are important to science. b. Students mathematically solve problems illustrating commonly accepted theories to show that the results match that observed, for example, the calculation of gravity or Avogadro's number, theoretical yields of a chemical reaction, confirmation of thermodynamic laws, illustration of Hardy-Weinberg equilibrium, etc. 2. Students can explain how science differs from other ways of understanding the world a. Students prepare a list of questions amenable to scientific inquiry and a list of questions that are not, and give reasons for their choices.
	b. Processes and results must be reproducible and subjected to peer review.	1. Students can explain the importance of reproducibility. a. Students explain what is meant by "reproducibility" and "peer review" as part of an exam, class assignment, or laboratory experiment. 2. Students contrast data gathered by different groups in a lab section about the same phenomenon; use averages to get a better picture of the relationship between the two variables.
	c. The results will display intrinsic variation and limitations.	1. Students can design and conduct an experiment that features replication, where they identify potential outliers and possible reasons for unusual data points.

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		a. Students throw a paper airplane *x* number of times and record distance or flight time, noting the variation in results. b. Students will explain the difference between precision and accuracy by making multiple measurements of density weighing water with pipette or other experimentally measured value. c. Students measure the mass of popcorn before and after popping to determine average Accumulate data and compare to other results.
	d. Continued scientific inquiry produces credible evidence that is used to develop scientific models and concepts.	1. Students provide examples of changing scientific thought regarding fundamental scientific concepts, for example: a. The progression of the understanding of evolution from Lamarckian evolution, to Darwinian evolution and our current understanding of epigenetics. b. A discussion reviewing the video, "A Tale of Two Mice - The Agouti Sisters." c. Students compare and contrast the plum pudding model and modern theory of the atom.
	e. Models and concepts that withstand the most wide-ranging and persistent critical analyses are assumed to most closely describe reality and the principles by which it operates.	1. Students report on an example of models and/or concepts from science that have withstood critical analysis of time) and those that ultimately have not, for example: a. Students compare and contrast the plum pudding model and modern theory of the atom. b. Students compare and contrast the heliocentric and geocentric model of the solar system. c. Students compare and contrast the phlogiston and oxidation explanation of fire and burning. 2. Students can use mathematical and other types of models to predict the behavior of a scientific system. a. Students mathematically solve problems illustrating commonly accepted theories to show that it matches that observed. For example, the calculation of gravity or Avogadro's number, theoretical yields of a chemical reaction, confirmation of thermodynamic laws, illustration of Hardy-Weinberg equilibrium, etc.

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Scientific Inquiry	demonstrate the application of specialized methods and tools of scientific inquiry by actively and directly collecting, analyzing, and interpreting data, presenting findings, and using information to answer questions.	1. Students describe the processes of collecting, analyzing, and interpreting data, including the description of their findings in a lab or field report, for example: a. Students write a procedure and then follow it to collect data for measuring the speed of sound. b. Explain the purpose of experimental controls. 2. Students use their senses and appropriate instruments to observe and accurately measure and analyze phenomena using SI units, such as: a. Students conduct single and double displacement chemical reactions, observe evidence of the reactions occurring, then correlate the physical reactions with the writing and balancing of the appropriate chemical equations. b. Students use appropriate equipment to the record the mass and volume of substances using significant figures. Using this data, students will graph mass and volume to determine the density of the substance 3. Students collect data on known and unknown samples then graph the data to determine the value of an unknown, such as: a. Students collect leaf pigment samples and use a spectral photometer to determine dominant feedback. 4. Students calculate and quantify the difference between two groups or systems, for example: a. Measure mass of kernels of popcorn before and after popping, calculate the percent of mass lost, and perform a statistical analysis on the loss. 5. Students use accepted vocabulary, symbols, and conventions to describe natural occurrence. 6. Students describe and represent significant changes in phenomena, such as: a. Students use gel electrophoresis to determine changes in the hemoglobin gene in cases of sickle-cell anemia. b. Students observe and classify whether changes are chemical or physical.

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		7. Students design an investigation to test a hypothesis, identifying the appropriate means of data collection and analysis necessary to do so. a. Students design different paper airplanes, hypothesize which fly fastest and farthest, and then test the designs using measuring tape and stopwatch. 8. Students draw conclusions to accept or reject hypothesis, support their findings, and answer questions using a provided data set and clearly communicate findings.
Core Concepts	accurately describe the scope of scientific study using core theories, practices and discipline-related terminology in two independent fields covering both a physical science and a life science.	1. Students apply the basic concepts, vocabulary, and models from a particular scientific discipline in order to solve a problem or carry out a task within that discipline, for example: a. Students use a pedigree to track sex-linked characteristics through a family. b. Students diagram the different stages of the life cycle of a fern plant and label them using specific terminology. c. Students explain the periodicity of the elements according to their placement in the periodic table. d. Students use a classification key to identify plant species. e. Students correctly solve problems and answer questions at the end of textbook chapter. f. Students develop a concept map for a set of vocabulary terms associated a text chapter. g. Students watch a video on the North American Wood frog and use colligative properties to explain how the frog freezes itself.
Scientific Literacy	(a) recognize the proper use of scientific data, principles and theories to assess the quality of stated conclusions; (b) demonstrate an ability to gather, comprehend, apply	1. Students can distinguish between scientific and pseudoscientific argumentation a. Students can read with understanding articles about science in the popular press and engage in discussion about the validity of the conclusions. For example: Read an article about the relationship between vaccination and autism, and engage in a discussion on the validity of the article's conclusions with their peers.

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	and communicate credible information on scientific and technical topics.	2. Students can apply learned scientific content to address a particular problem or question of interest. Students identify scientific issues underlying national and local decisions and defend positions that are scientifically and technologically informed. For example: a. Students view an online TED talk dealing with global warming and afterwards engage in an online of the validity of the arguments and evidence presented. b. Students can evaluate the quality of scientific information on the basis of its source and the methods used to generate it, for example c. Students select an advertisement for a product or service and evaluate the validity of the scientific claims used to promote it. d. Students will pose and evaluate arguments based on evidence and apply conclusions from such arguments. For example: i. Students investigate the reported health benefits of an item such as magnets or copper bracelets and report on the scientific basis for these claims.
Scientific Reasoning	demonstrate scientific reasoning processes to draw conclusions.	1. Students demonstrate proficiency on an accepted scientific reasoning assessment, such as the Madison Assessment or Lawson Test. 2. Students draw appropriate conclusions from laboratory or field activities or case studies, and communicate the results to others. a. Students can explain why cans of diet soda and regular soda will display different buoyancy properties when placed in a tank of water. b. Students use the results of a natural selection experiment, such as the rise of multi-drug resistant pathogens, to explain phenotypic variations of a population. 3. Students identify the appropriate methodologies (qualitative and quantitative) to analyze and solve a scientific problem. Examples might include: a. Students determine the originator of a simulated epidemic. Students carry out a simulation of the spread of infection using the standard classroom 'candy' sharing exercise.

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		b. Students determine the appropriate cation-anion detection method to determine an unknown salt. c. Students write a procedure and the follow it to collect data for measuring the speed of sound. 4. Students can identify and quantify patterns and observations. Examples might include: a. Students build and separate macromolecules to show that dehydration synthesis is a common chemical reaction used to form the major macromolecules in biological systems. e. Students distinguish various groups of organism using shared and non-shared characteristic.
Ethics	demonstrate an understanding of the standards that define ethical scientific behavior, including: a. Honesty: the accurate use and reporting of scientific processes, data, and results, and the proper sharing of credit among colleagues. b. Safety: ensuring the safety and well-being, both mental and physical, of practitioners, test subjects, local community, and environment.	1. Students distinguish ethical from non-ethical scientific behavior using examples (actual or hypothetical); explain the reasons for the decisions. a. Students read several scenarios in which there are "gray areas" in the conducting of an experiment, interpreting or publishing of data. Students respond to these scenarios with a description of their course of action, and the reasons for their decisions. 2. Students accurately report/represent their findings in a lab or field report, presentation, or paper, using proper citation of sources and collaborations. a. Students describe the impact of falsified data on the validity of scientific conclusions and the reputation of science in general, using the Jan Hendrick Schön or cold fusion cases as an example. b. Students will use the Watson-Crick DNA case study to discuss the importance of proper attribution of scientific credit. 3. Students display an awareness of the importance of the safety and well-being of the scientific researchers, participants, and the environment during a scientific experiment. Examples might include: a. Students are able to identify the location of basic safety equipment used in laboratory and field activities and demonstrate their proper use.

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	c. Social Responsibility: recognition of the impact of our actions on the natural and human world.	b. Students do a search and hunt exercise to learn the safety features presented in chemical safety data sheets. c. Students carry out laboratory exercises in which they demonstrate the proper disposal of harmful materials. 4. Students will report on the way scientific ethics have evolved over time For example: a. Using case studies such as the Tuskegee Experiment and the case of the Henrietta Lack cell line, students engage in discussion about the growth and development of the IRB and IACUC guidelines. b. Students calculate their carbon footprint using www.myfootprint.org. c. Students participate in a classroom discussion that weighs the benefits and environmental costs of activities such as fracking, oil extraction in the Amazon. d. Students evaluate discrepancies, such as wealth and health, among societies using www.gapminder.org.
Science and Society	understand the role science plays in historical and contemporary issues.	1. Students identify the scientific context that helped frame a past social issue (e.g., fluoridation, eugenics, antisepsis and germ theory, Love Canal, detergent additives) a. Students write a review of the movie "Inherit the Wind" based on their knowledge of the actual Scopes trial and discuss what that trial would be like if it took place today. b. Students watch the documentary "The Polio Crusade" on the polio virus and write report on necessity to develop a polio vaccine. 2. Students evaluate and explain the scientific evidence and reasoning underlying a contemporary scientific debate. a. Students engage in a classroom discussion on climate change. b. Students read recent news reports on outbreaks of measles and whooping cough, evaluate the safety and efficacy of vaccinations, and debate the pros and cons of mandatory vs. voluntary vaccinations

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		c. Students watch the movie “Gattaca” and discuss it in the context of “designer babies,” genetically modified children, and selecting for specific genetic traits in children. 3. Through course assignments, laboratory experiments, or discussions, students examine the impact of science and technological advances on work, recreation, communication, economic systems, social relationships, health, privacy, and environmental sustainability.