Chief Reader Report on Student Responses:

2024 AP® Environmental Science Set 2

Free-Response Questions

- Number of Students Scored 236,579
- Number of Readers 835
- Score Distribution

Exam Score	N	%At
5	21,774	9.2
4	65,057	27.5
3	41,232	17.4
2	61,009	25.8
1	47,507	20.1

- Global Mean 2.80

The following comments on the 2024 free-response questions for AP® Environmental Science were written by the Chief Reader, Laura J. Hainsworth, Professor of Chemistry and Environmental Studies, Emory & Henry University. They give an overview of each free-response question and of how students performed on the question, including typical student errors. General comments regarding the skills and content that students frequently have the most problems with are included. Some suggestions for improving student preparation in these areas are also provided. Teachers are encouraged to attend a College Board workshop to learn strategies for improving student performance in specific areas.

Question 1

Task: Design an Investigation
Topic: Succession Diagram and Deforestation
Max Score: 10
Mean Score: 3.89

What were the responses to this question expected to demonstrate?

The intent of this question was for students to demonstrate an understanding of primary succession and the formation of soil during primary succession. Students also needed to demonstrate the experimental design aspects of an independent variable, a control, and writing a testable hypothesis in the context of clear-cut and intact forests along water quality.

In parts (a–d), students were asked to use a diagram to identify the type of succession and the stage at which pioneer species appeared [Science Practice 2 Visual Representations and Topic 2.1 Ecological Succession]. Students were also asked to describe how soil formation happened during primary succession [Science Practice 1 Concept Explanation and Topics 2.1 Ecological Succession and 4.2 Soil Formation and Erosion]. Finally, students were asked to identify a cultural ecosystem service that may be provided by a mature forest [Topic 2.2 Ecosystem Services].

In parts (e–h), students were asked to identify and describe aspects of an experimental design that compared forested and clear-cut areas [Science Practice 4 Scientific Experiments]. Students were also asked to explain how clear-cutting would impact water temperature [Science Practice 1 Concept Explanation and Topic 5.2 Clearcutting].

In parts (i–j), students were asked to explain how water quality (other than temperature) and aquatic organisms would be impacted if a golf course were built on clear-cut land. [Science Practice 1 Concept Explanation and Topics 8.2 Human Impacts on Ecosystems and 8.5 Eutrophication].

How well did the responses address the course content related to this question? How well did the responses integrate the skill(s) required on this question?

- In part (a), most of the responses correctly applied Topic 2.1 Ecological Succession and identified primary succession as the ecological process that is shown in the diagram.
- In part (b), most responses correctly identified stage II/2 as the stage where pioneer species first appear.
- In part (c), students were asked to describe how soil forms from stage II to stage III. Correct responses described the action of an agent, for example lichens/algae/fungi, breaking down rock.
- In part (d), most responses correctly identified a cultural ecosystem service. Responses that did not earn a point in part (d) identified a provisioning service.
- In part (e), students were asked to identify a testable hypothesis. Many responses successfully identified a hypothesis that included either a null effect or a directional effect (increase/decrease) of the independent variable on the dependent variable. Responses that did not earn a point in part (e) used qualitative words like worse/better instead of increase/decrease.
- In part (f), most responses correctly identified the independent variable for the experiment.

- In part (g), students were asked to describe the purpose of forest A in the diagram provided. This was challenging for students because the task verb "describe" requires a characteristic of what is identified. To earn the point in part (g), responses needed to describe an experimental control. For example, "forest A is included to compare the intact forest to the clear-cut forest."

- In part (h), students were asked to explain why water temperature might change because of clear-cutting. Many responses earned a point by correctly explaining how clear-cutting would lead to an increase in water temperature. Some only restated that water temperature changed and did not earn a point.

- In part (i), students were asked to explain why a water quality indicator (other than temperature) could undergo change after the addition of the golf course in forest B. This was a challenge because in addition to selecting an appropriate indicator of water quality, students were expected to articulate the connection between the new golf course and the change in that indicator.

- In part (j), students were asked to explain how aquatic organisms in the lake would be affected by the addition of the golf course. Many explanations dealt with increased sedimentation resulting from clear-cutting instead of the effects of the golf course. In addition, many responses confused freshwater ecosystems with marine ecosystems. Students earned a point in part (j) by explaining what caused the aquatic organisms to die/survive (for example, lack of oxygen) and the mechanism (for example, decomposition of algae).

What common student misconceptions or gaps in knowledge were seen in the responses to this question?

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
• A common misconception was that the amount of dissolved oxygen in water causes an increase/decrease in the water temperature when a forest is clear-cut.	• "The temperature of the water in forest B might change because the trees can't act as shade for the water. Because forest B is clear-cut there is more sunlight hitting the water. Therefore, the temperature of the water increases."
• A common misconception was that sediment in the water would increase albedo due to increased absorption of sunlight as a result of clear-cutting.	• "Water temperature will increase as a result of more sedimentation. The sediment will darken the water, lowering the albedo which means the water will absorb more sunlight."
• A common knowledge gap was expressing the connection between a change in a water quality indicator and the source of that change.	• "Golf courses may use increased amounts artificial nitrogen fertilizers to maintain their grass. The runoff from the course could contain these fertilizers, causing eutrophication and an algal bloom. When this algae dies, decomposers will use the dissolved oxygen during decomposition of the algae, and this lowers the dissolved oxygen."

• A common misconception was that a hypothesis is a question rather than a testable statement.	• "Clear-cutting trees will lead to an increase in water temperature."

Based on your experience at the AP® Reading with student responses, what advice would you offer teachers to help them improve student performance on the exam?

- Provide ample opportunity for students to build their skills in designing and implementing their own experiments, preferably through laboratory exercises. This should include emphasizing key concepts such as the scientific question, the hypothesis, the independent variable, the dependent variable, and the function of a control in an experiment. Laboratories are also a great way to reinforce course content.
- Starting the first few weeks of the school, introduce and provide frequent student reminders throughout the year regarding the differences required by the task verbs. Incorporate the task verbs into the classroom at every opportunity possible. For example, in part (g) a common gap in knowledge was the identification of the purpose of forest A (e.g., "forest A is a control") instead of describing the purpose of forest A (e.g., "inclusion of forest A allows researchers to compare intact areas to clear-cut areas").
- Students should not just repeat the prompt to generate their answer. These responses do not earn points because they are missing additional required information, such as a description or explanation.
- Encourage students to read all parts of each free-response question carefully, including the short passages that precede the prompt or a diagram. These passages contain information that can steer students toward an acceptable response. Before part (i), the short passage indicates "the researchers are interested in the effect the golf course may have on the water quality of the river." Many responses that did not earn a point in part (i) included explanations that dealt with the clear-cutting instead of the addition of a golf course.

What resources would you recommend to teachers to better prepare their students for the content and skill(s) required on this question?

Resources for enriching content across topics:

- AP Daily videos in AP Classroom are available for every topic in AP Environmental Science. Teachers can integrate these videos into their instruction to provide students with additional exposure to content throughout the course.
- AP Daily Live videos found on YouTube provide a comprehensive review of the course content for students. Teachers can assign these videos in the weeks leading up to the exam to strengthen their understanding of course content.
- AP Faculty Lectures are a collection of videos available on YouTube that provide an in-depth look at specific course content from the perspective of higher education faculty at a variety of colleges and universities.
- On the AP Environmental Science Online Teacher Community there are many resources, discussions, tips, and activities that many teachers have found helpful. It is easy to sign up, and teachers can search through topics of discussions from previous years.

To better engage students with Science Practice 4 (Scientific Experiments) and Science Practice 5 (Data Analysis):

- Teachers are strongly encouraged to use the laboratories available in AP Classroom. Each lab is designed to target specific Science Practice Skill development, including the articulation of hypotheses and interpreting data with respect to specific hypotheses.
- Consider a project-based learning approach (PBL) to environmental science. Research indicates students who engage in project-based AP coursework are more likely to earn a qualifying score of 3 or higher on the AP Exam. For instructors new to the PBL approach, College Board has developed a year-long sequence of PBL modules specifically designed for AP Environmental Science. For more information, visit https://apcentral.collegeboard.org/professional-learning or contact approjectbasedlearning@collegeboard.org.

For reviewing task verbs and practicing responses:

- Sample student responses for this question can be found on the exam information page on AP Central, along with commentary explaining why each point was or was not earned. Teachers can use these samples to better understand how each question was scored and to work with students to practice writing correct responses.
- Scoring guidelines for this question can be found on the exam information page on AP Central. Teachers can use and adapt these scoring guidelines throughout the course so that students become familiar with how their responses will be scored.
- In AP Classroom, the Review section under the Course Guide contains numerous practice videos that walk students through the process of reading and responding to FRQs.
- Have students practice, score, and review examples of FRQ 1 on the released 2021–2024 AP Environmental Science Exams. These can be found on the exam information page on AP Central. Student samples and scoring guidelines are also available for those questions.
- In AP Classroom, teachers can access a rich collection of resources that includes formative and summative assessment items for every unit of the course.

Training and additional instructional support:

- Sign up for an AP Summer Institute (APSI). This is a great way for instructors to gain in-depth knowledge about the AP Environmental Science curriculum and exam. It is also a great opportunity to network with colleagues from around the world.
- Apply to be an AP Reader. The AP Reading provides an outstanding professional development opportunity. In addition to providing an in-depth, hands-on experience with how to accurately apply AP scoring guidelines, the AP Reading is a great way to share resources and network with colleagues.
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Question 2

Task: Analyze an Environmental Problem and Propose a Solution
Topic: Change in Habitable Land Graph
Max Score: 10
Mean Score: 4.75

What were the responses to this question expected to demonstrate?

The intent of this question was for students to demonstrate their ability to interpret a graph of land use changes from 1700–2018 and consider the implications of those changes in different scenarios. This question focused on broad topics such as the carbon cycle, water resources, and ecosystem dynamics. Concepts such as photosynthesis, urbanization, the hydrologic cycle, water pollution, conservation, and wildlife population dynamics were relevant.

In parts (a–c) students were asked to interpret the graph showing land use change over time and identify the year with the highest percent of forest cover, describe the relationship between wild grassland and grazing land uses from 1700–1950, and identify an environmental problem associated with overgrazing [Science Practice 5 Data Analysis and Topics 5.4 Impacts of Agricultural Practices, 4.3 Soil Formation and Erosion and 9.10 Human Impacts on Biodiversity].

In part (d) students were asked to evaluate a hypothesis about atmospheric carbon dioxide concentrations over time and explain whether the hypothesis is supported or refuted. The students needed to use information from the graph and discuss the hypothesis in the context of land use change and photosynthesis or the carbon cycle [Science Practice 5 Data Analysis and Topics 5.2 Clearcutting, 1.4 The Carbon Cycle, and 9.4 Increases in the Greenhouse Gases].

In parts (e) and (f) students were expected to describe an environmental problem related to water that is caused by urbanization and described a response to mitigate the problem [Science Practice 7 Environmental Solutions and Topics 1.7 The Hydrologic Cycle, 5.10 Impacts of Urbanization, and 5.13 Methods to Reduce Urban Runoff].

In parts (g) and (h) students were required to explain why there are fewer bobcats present on farmland than in the past and described a disadvantage of introducing a small population of bobcats [Science Practice 1 Concept Explanation and Topics 2.3 Island Biogeography, 3.4 Carrying Capacity, 3.5 Population Growth and Resource Availability, and 9.10 Human Impacts on Biodiversity].

In part (i) students were asked to propose a solution to improve the likelihood of successfully reintroducing bobcats and reestablishing a wild population. In part (j), students were asked to justify their proposed solution by describing an additional advantage of the solution that is not related to reestablishing bobcats [Science Practice 7 Environmental Solutions and Topics 2.3 Island Biogeography, 3.4 Carrying Capacity, 3.5 Population Growth and Resource Availability, and 9.10 Human Impacts on Biodiversity].

How well did the responses address the course content related to this question? How well did the responses integrate the skill(s) required on this question?

- In part (a) most students correctly applied Science Practice 5 Data Analysis and used the graph to identify "1700" as the year with the most forested land. Similarly in part (b) most students correctly described an increase in grazing and a decrease in wild grasslands or an inverse relationship.

- In part (c) most students correctly referenced Topic 5.4 Impacts of Agricultural Practices to identify an environmental problem associated with overgrazing. The most common responses were loss of vegetation and soil erosion. Soil compaction and desertification were also common.

- In part (d) many students correctly explained that the hypothesis was refuted because forest cover decreased over time, which means that there is less photosynthesis, less carbon sequestration, or a diminished carbon sink to remove carbon dioxide from the atmosphere.

- In part (e) most students correctly described a water-related problem associated with urbanization and the most common response was runoff due to impervious surfaces. Water pollution from runoff and decreased groundwater resources were also described frequently.

- In part (f) most students correctly described a response to mitigate the problem described in part (e). Increasing permeable surfaces was the most common response and creating green space was also described frequently.

- In part (g) most students correctly explained that there are few bobcats present on farmland because the forest was cleared, which forced them to migrate/move to new habitats or decreased the availability of food, shelter, or mates.

- In part (h) many students correctly described that introducing a small population of bobcats would be a disadvantage as it would result in lower genetic diversity, inbreeding depression, or bottlenecks. Some students described that smaller populations are less likely to survive, and some described that lower numbers of bobcats will not effectively control the small mammals that the farmers consider pests.

- In part (i) many students proposed a correct solution to improve the success of reestablishing bobcats by increasing connectivity between forest patches with forested corridors or by reforesting cleared land to create new bobcat habitat.

- In part (j) many students correctly justified the solution proposed in part (i) by describing an additional advantage such as other species using the corridors, which would increase their populations or overall biodiversity. Some students justified the solution by indicating that replanted trees for corridors or habitat can serve as a carbon sink or reduce soil erosion.

What common student misconceptions or gaps in knowledge were seen in the responses to this question?

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
• Some responses to part (d) did not demonstrate a complete understanding of forests performing photosynthesis or sequestering carbon or acting as a carbon sink. For example, incorrect responses sometimes indicated that trees store carbon dioxide rather than carbon.	• "The students hypothesis is refuted by the data in the graphs. The graph shows a decrease in forest, which means there has been an increase in atmospheric carbon dioxide concentrations because forests are a major carbon sink."
• A misconception in part (h) is that small populations of bobcats result in a lower reproductive rate rather than lower genetic diversity, inbreeding, bottlenecks, or genetic drift.	• "Having only a small number of bobcats will decrease the genetic diversity of bobcats making them more vulnerable to disease."
• Some responses to part (g) indicated a knowledge gap in how the loss of habitat can lead to fewer bobcats.	• "As the forest is clearcut, the bobcat loses the natural habitat that allows it to successfully hunt."

Based on your experience at the AP® Reading with student responses, what advice would you offer teachers to help them improve student performance on the exam?

- Students should read prompts carefully and not overlook information embedded among prompt stems. For example, there were two short paragraphs in the prompt after parts (f) and (g) that were critical to correctly answering some prompt stems. The prompt text indicates that "They can introduce only a small number of bobcats in each patch." However, many students responded "release a larger group of bobcats" for part (i).
- Remind students to read the prompt stem for each part of the question carefully. The prompt stem for part (j) specifies "...other than reestablishing the bobcat population near the farms." Many responses provided justifications based on bobcats preying on small mammal pests.
- Clarify with students that adaptation refers to an evolutionary process where species adjust to new or changing conditions across generations. In part (h) many students described "inability to adapt" as a disadvantage of introducing a small population of bobcats, but the bobcats were reintroduced to their natural forest habitat and adaptation does not happen within the lifetime of an organism.

What resources would you recommend to teachers to better prepare their students for the content and skill(s) required on this question?

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To better engage students with Science Practice 5 (Data Analysis):

- Teachers are strongly encouraged to use the laboratories available in AP Classroom. Each lab is designed to target specific Science Practice Skill development, including the articulation of hypotheses and interpreting data with respect to specific hypotheses.
- Consider a project-based learning approach (PBL) to environmental science. Research indicates students who engage in project-based AP coursework are more likely to earn a qualifying score of 3 or higher on the AP Exam. For instructors new to the PBL approach, College Board has developed a year-long sequence of PBL modules specifically designed for AP Environmental Science. For more information, visit https://apcentral.collegeboard.org/professional-learning or contact approjectbasedlearning@collegeboard.org.

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- Scoring guidelines for this question can be found on the exam information page on AP Central. Teachers can use and adapt these scoring guidelines throughout the course so that students become familiar with how their responses will be scored.
- In AP Classroom, the Review section under the Course Guide contains numerous practice videos that walk students through the process of reading and responding to FRQs, including dimensional analysis for questions that require mathematical operations and application of task verbs.

- Have students practice, score, and review examples of FRQ 2 on the released 2021–2024 AP Environmental Science Exams. These can be found on the exam information page on AP Central. Student samples and scoring guidelines are also available for those questions.
- In AP Classroom, teachers can access a rich collection of resources that includes formative and summative assessment items for every unit of the course.

Training and additional instructional support:

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Question 3

Task: Analyze an Environmental Problem and Propose a Solution Doing Calculations
Topic: Deserts, Forests, and Lake Powell Calculations
Max Score: 10
Mean Score: 4.08

What were the responses to this question expected to demonstrate?

Parts (a) and (b) required students to demonstrate understanding of ecological tolerance in desert biomes [Science Practice 1 Concept Explanation and Topics 1.2 Terrestrial Biomes, 2.4 Ecological Tolerance, and 2.6 Adaptations] and to justify the proposed solution to the overuse of water for irrigation by describing an additional benefit other than water reduction, which could be ecological, economic, cultural, or environmental [Science Practice 7 Environmental Solutions and Topics 2.2 Ecosystem Services, and 2.4 Ecological Tolerance].

In parts (c) and (d), students were expected to demonstrate an understanding of how prescribed burns are used [Science Practice 7 Environmental Solutions and Topics 2.5 Natural Disruptions to Ecosystems and 5.17 Sustainable Forestry], and the negative effects of prescribed burns on forested ecosystems, the atmosphere, or water quality. [Science Practice 7 Environmental Solutions and Topics 1.2 Terrestrial Biomes, 2.5 Natural Disruptions to Ecosystems, 5.17 Sustainable Forestry, and 7.4 Atmospheric CO_2 and Particulates].

In parts (e), (f), and (g) students were required to calculate answers associated with water volumes and flow in Lake Powell [Science Practice 6 Mathematical Routines and Topics 1.7 The Hydrologic (Water) Cycle, 2.5 Natural Disruptions to Ecosystems, and 9.5 Global Climate Change]. Part (e) required students to calculate the volume of water in Lake Powell in 2021 given the lake's capacity and the percentage full. In part (f) the students were asked to calculate the amount of water contributed to Lake Powell by mountain snowmelt given the average annual watershed contribution, the percentage from snowmelt, and the 2021 percentage of average river flow. Finally, part (g) required students to calculate the number of households that could be supported by the average flow of water into Lake Powell given the average water consumption of a household. While dimensional analysis based on unit cancellation is recommended, a setup point was earned for responses showing correct values and mathematical operations.

How well did the responses address the course content related to this question? How well did the responses integrate the skill(s) required on this question?

- Students showed knowledge of adaptations of plants in the desert biome and the use and side effects of prescribed burns to reduce forest fires. Students were expected to be able to set up and evaluate basic calculations, showing correct numeric values and arithmetic operations, and report answers in correct units.

- In part (a) students were highly successful at identifying a type of plant that would be used in desert-tolerant landscaping, most frequently cacti.

- In part (b) correct responses justified the removal of non-native grass lawns and landscaping with non-water consumption related advantages. Many described how replacement with native plants provided habitat for local wildlife or reduced the need for fertilizers or pesticides. Some students described how the lack of mowing resulted in less time, labor, and money spent on maintenance.

- Correct responses in part (c) described how prescribed fires would burn the undergrowth and dead biomass on the forest floor, reducing the amount of flammable material that would fuel forest fires, causing them to be less severe or less able to spread.
- In part (d), many students described how prescribed burns could harm or reduce habitat for wildlife. Some students correctly described that prescribed burns release CO_2, which leads to increased global warming or that prescribed burns release particulate matter (ash, smoke), which worsens air quality.
- In parts (e), (f), and (g), students calculated the amount of water in Lake Powell in 2021, the flow into Lake Powell from mountain snowmelt, and the number of households that could be supported by the average flow into Lake Powell. Many students were able to correctly utilize scientific notation and unit cancellation and report their answer in appropriate units.

What common student misconceptions or gaps in knowledge were seen in the responses to this question?

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
• A common misconception was that prescribed burns would consume all biomass, including mature healthy trees, in a forest.	• "A prescribed burn would rid the forest of dead & dry shrubs & underbrush without damaging other plants. In the event of a forest fire, there would then be less to burn & less of a chance of the fire spreading further."
• Some responses struggled with the unit "million acre-feet" in (e) and (f), writing the starting value in acre-feet, such as writing 25.16 maf as "25,160,000" and then calculating an answer which was six orders of magnitude larger than the correct answer, such as "9,057,600 maf".	• $25.16 \times 0.36 = 9.0576$ maf
• Some responses used cross-multiplication strategies to calculate percentages of a total, but did not show all numeric values and operations. Some responses started with a correct equivalence statement such as "$\frac{25.16}{100} = \frac{x}{36}$" but continued to "$100x = 905.76$" without showing the mathematical operations to get 905.76. Other responses incorrectly used multiplication symbols instead of "=" in a cross-multiplication setup, such as "$\frac{25.16}{100}, \frac{x}{36} = 9.0576$".	• $\frac{25.16}{100} = \frac{x}{36}$ • $100x = 36 \times 25.16$ • $x = \frac{905.76}{100} = 9.0576$

Based on your experience at the AP® Reading with student responses, what advice would you offer teachers to help them improve student performance on the exam?

- Students should learn to write a mathematical expression (or series of expressions) that shows all necessary mathematical operators and every step in their calculations. Students should also practice both multiplying and dividing by numbers written in scientific notation and practice doing this with the specific calculator they will use for the exam.
- Students should learn that a "justify the solution" task verb is more complex than "identify a benefit" and be prepared to not only name a benefit of the solution but also describe how it is beneficial.
- Remind students to read each question carefully and respond to the prompt as presented, noting if the prompt specifies a specific type of effect or a phrase such as "other than."

What resources would you recommend to teachers to better prepare their students for the content and skill(s) required on this question?

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To practice reading and responding to questions:

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- Scoring guidelines for this question can be found on the exam information page on AP Central. Teachers can use and adapt these scoring guidelines throughout the course so that students become familiar with how their responses will be scored.
- In AP Classroom, the Review section under the Course Guide contains numerous practice videos that walk students through the process of reading and responding to FRQs, including dimensional analysis for questions that require mathematical operations.

- Have students practice, score, and review examples of FRQ 3 on the released 2021–2024 AP Environmental Science Exams. These can be found on the exam information page on AP Central. Student samples and scoring guidelines are also available for those questions.

- In AP Classroom, teachers can access a rich collection of resources that includes formative and summative assessment items for every unit of the course.

To better engage students with Practice 6 (Mathematical Routines):

- Teachers are strongly encouraged to use the laboratories available in AP Classroom. Each lab is designed to target specific Science Practice Skill development, including mathematical routines.

- Consider a project-based learning approach (PBL) to environmental science. The PBL approach integrates mathematical routines with student investigation of real-life scenarios in environmental science. Research indicates students who engage in project-based AP coursework are more likely to earn a qualifying score of 3 or higher on the AP Exam. For instructors new to the PBL approach, College Board has developed a year-long sequence of PBL modules specifically designed for AP Environmental Science. For more information, visit https://apcentral.collegeboard.org/professional-learning or contact approjectbasedlearning@collegeboard.org.

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Training and additional instructional support:

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