Chief Reader Report on Student Responses:

2022 AP® Environmental Science Set 1

Free-Response Questions

- Number of Students Scored 179,957
- Number of Readers 521
- Score Distribution

Exam Score	N	%At
5	16,006	8.9
4	49,226	27.4
3	31,557	17.5
2	46,581	25.9
1	36,587	20.3

- Global Mean 2.79

The following comments on the 2022 free-response questions for AP® Environmental Science were written by the Chief Reader, Laura Hainsworth, Professor Emery & Henry College. 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: Aquatic and Terrestrial Pollution and Impacts of Agricultural Practices
Max Score: 10
Mean Score: 3.29

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 diagram of the distribution of turtle nests on a river and to identify components of a scientific experiment. Students were asked to explain concepts related to bioaccumulation, biomagnification, and the formation and effects of mercury. Students were also expected to convey an understanding of the impact of agricultural techniques on soils.

In part (a) students were expected to demonstrate their ability to read and interpret information provided in a diagram [Practice 2 Visual Representations]. They were then asked to use the information provided to identify various parts of scientific experiments and explain the result of modifications to the experiment [Practice 4 Scientific Experiments].

In part (b) students were asked to describe the effect of mercury at both the organism and ecosystem level and how methylmercury is formed [Practice 1 Concept Explanation, Topic 8.2 Human Impact on Ecosystems, Topic 8.7 Persistent Organic Pollutants, and Topic 8.8 Bioaccumulation and Biomagnification]. In addition, they were asked to explain how a claim about how the impact of mercury on turtle nest success was supported or refuted using information provided in the diagram [Practice 2 Visual Representations].

In part (c) students were asked to explain the impacts of agricultural practices on soil [Topic 5.4 Impact of Agricultural Practices].

How well did the responses address the course content related to this question? How well did the responses integrate the skills required on this question?

Students were expected to demonstrate the ability to interpret diagrams and identify and describe experimental design components. Students were also expected to demonstrate concept knowledge about bioaccumulation, biomagnification, the effect of persistent pollutants and the impacts of agricultural practices.

- Responses in part (a) were related to Science Practice 2 Visual Representations and Science Practice 4 Scientific Experiments. In part (a)(ii) most students correctly identified the dependent variable as "success rates of turtle nests." Part (a)(iii) required students to identify a scientific question for the study based on the information provided. Correct responses were written as a question and included the effect of mercury on either the location or success of the nest. Part (a)(iv) required students to describe that the measurements of mercury upstream acted as a control for the study. Many students answered "to have it as a control" or described the control as being used to "compare the nests with no mercury upstream to the nests with mercury downstream." In part (a)(v) students had to predict and explain how a modification to the environment would affect the success rates of turtle nests [Science Practice 1 Concept Explanation]. Students who answered this successfully included the predicted change in the environment, the change in successfulness of the nests and explained how the change in the environment resulted in the change in success rates. A correct answer could explain the location of the nests moving closer to the river, less vegetation to filter out the mercury, or more erosion. "Removing trees and other vegetation from the river bank would result in less successful nests due to

them now being located closer to the river. Mercury levels are higher closer to the river, exposing the nests to more mercury and making them less successful."

- Responses in part (b) were related to Science Practice 1 Concept Explanation and Science Practice 2 Visual Representations. In part (b)(i) students were expected to describe either the concept of bioaccumulation [Topic 8.8 Bioaccumulation and Biomagnification] or the impact of persistent pollutants such as mercury on an organism [Topic 8.3 Endocrine disruptors, Topic 8.7 Persistent Organic Pollutants]. Responses describing bioaccumulation were most common. Other answers focused on the effect of persistent pollutants on a particular organ system. "Mercury is a neurotoxin that leads to damage of the brain and nervous system." Part (b)(ii) focused on the impact of persistent pollutants in the ecosystem [Topic 8.8 Bioaccumulation and Biomagnification]. Part (b)(iii) asked students to explain how methylmercury would be present in the stream [Science Practice 2 Concept Explanation and Topic 8.2 Human Impact on Ecosystems]. To correctly answer this part of the question, students needed to indicate mercury was discharged into the river from the factory where it was converted to methylmercury in the river sediments or water by bacteria. In part (b)(iv) students were expected to use information from the provided diagram to support or refute the claim that "soil nearest to the river has higher levels of mercury than the field has." [Science Practice 2 Visual Representations]. Students indicated that the claim was supported using data on the location of unsuccessful nests in Area B. "The pattern shown in the diagram supports the claim that the soil nearest to the river has higher levels of mercury than the field does. This claim is supported because those nests closest to the river in Area B were unsuccessful while the ones further in the field were successful."

- Responses in part (c) described how a specific agricultural practice changes soil [Science Practice 1 Concept Explanation and Topic 5.4 Impact of Agricultural Practices]. Students needed to indicate the agricultural practice and describe how it changed soil or soil properties to earn the point. "Tilling soil causes soil erosion because tilling disrupts and loosens soil, which means that soil is more easily blown away."

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

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
• One common knowledge gap was the students' ability to explain how methylmercury forms. Students often responded that methylmercury was released directly from the factory or resulted from a reaction with the pollutant methane.	• "Methylmercury can be present in the stream because the mercury pollutants from the factory are converted to methylmercury in the water by bacteria." • "Methylmercury could be present in the stream because when chemical factories release inorganic mercury into bodies of water, bacteria can convert this mercury to organic methylmercury through the process of methylation."
• One common misconception was linking a decrease in water quality from erosion to a decrease in nesting success rates on the floodplain. "Removing trees and vegetation along the banks can cause erosion, making sediments cloud the waters, making turtle nesting less successful."	• "Removing trees along the riverbank will decrease the amount of successful nests. With less vegetation, there will be less roots to hold soil in place and secure the stream bed. Water from the stream will erode the edges of the stream, causing the shorelines to fall back and reducing area for nests."
• One common misconception was students interpreting conservation of soil as a change in soil. In part (c), students were asked to describe how an agricultural practice changed soil. Many students described how an agricultural practice conserved soil, rather than changed it. "Crop rotation conserves nutrients in the soil."	• "Monocropping is the planting of only one crop at a time. This depletes the soil of nutrients." • "Plowing soil loosens the soil and leaves it vulnerable to erosion."

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

- Remind students of the differences required by the task verbs found in the question. "Identify" requires a very short response and does not require an explanation for a point. On the other hand, students should have practice explaining concepts and answers in preparation of the more detailed answer required from an "explain" task verb. Students need to know they should provide more than a vocabulary term when asked for a description of a concept.
- The skills in Practice 2 Visual Representations ask students to analyze representations of environmental concepts and processes. These skills should be practiced in class so that students can practice how to read and interpret diagrams. They should have experience using a key and drawing conclusions based on provided information. Warmups with diagram interpretation can be used for quick practice on this skill.

- The skills in Practice 4 (Scientific Experiments) should be practiced often in class. Students should practice developing their own independent and dependent variables, constants, and controls with student driven experiments in class. They also should have practice identifying these concepts from a written description of an experiment to prepare them for this portion of the question.

- Students should understand the difference between asking a scientific question and stating/evaluating a hypothesis. Prior to this course, many students have only been taught about hypotheses and might not be familiar with the concept of scientific questions.

- Students should focus on vocabulary found in the CED. For example, they should understand how neurotoxins and endocrine disruptors impact organisms. Students should understand the difference between bioaccumulation and biomagnification and understand which term applies to organisms and which term applies to ecosystems.

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

- Teachers will find sample student responses for this question 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 the question was scored and to work with students to help practice writing correct responses.

- Teachers will find scoring guidelines for this question explaining how the question was scored 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.

- Teachers can have students practice with the examples of FRQ 1 on the released 2021 and 2022 AP Environmental Science Exams found on the exam information page on AP Central. Student samples and scoring guidelines are also available for those questions.

- Teachers can have students practice, score, and review the examples of FRQ 1 found on the three AP Environmental Science Practice Exams that can be accessed in AP Classroom.

- Teachers can use the labs that are available in AP Classroom with their students. Each lab is designed to target specific skill development.

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

- AP Daily videos in AP Classroom provide enriching content for every topic in AP Environmental Science. Teachers can integrate these videos into their instruction in a variety of ways 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 to students in the weeks leading up to the exam to reinforce content learned throughout the course.

- AP Faculty Lectures are a collection of videos available in 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.
- Teachers might consider signing up for an AP Summer Institute (APSI). An APSI is a great way to gain in-depth knowledge about the AP Environmental Science curriculum and exam. It is also a great way to network with colleagues from around the world.
- Teachers with more experience (a minimum of 3 years is required) might consider applying to be an AP Reader. The AP Reading is considered outstanding professional development by most AP teachers. Besides learning how to accurately apply AP scoring guidelines to score student responses, it is a great way to share resources and network with colleagues.

Question 2

Task: Analyze an Environmental Problem and Propose a Solution
Topic: Fracking and Air Quality
Max Score: 10
Mean Score: 3.53

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 and to provide an environmental solution to a given environmental problem. Students were expected to convey an understanding of resource use and air quality improvements.

In part (a) students were asked to analyze a graph of methane concentrations in drinking water wells in Pennsylvania, and to derive quantitative data from the graph [Practice 5 Data Analysis, Topic 6.5 Fossil Fuels]. Students were then asked to identify one negative geologic effect in an area where hydraulic fracturing (fracking) occurs.

In part (b) students were asked to identify the environmental concept illustrated by an example of overuse of a shared resource [Topic 5.6 Tragedy of the Commons] and then describe the effect of increased groundwater use in applied contexts [Topic 1.7 The Hydrologic Cycle, Topic 8.2 Human Impacts on Ecosystems, Topic 5.10 Impacts of Urbanization]. The task required students to apply Practice 1 Concept Explanation and Practice 7 Environmental Solutions.

In part (c) students were asked to make a claim and justify a realistic governmental action to improve air quality by reducing oil consumption. This part required students to apply content from Topic 7.1 Introduction to Air Pollution, Topic 8.2 Human Impacts on Ecosystems, and Topic 6.3 Energy Conservation and skills from Practice 7 Environmental Solutions to appropriately respond to the prompt.

How well did the responses address the course content related to this question? How well did the responses integrate the skills required on this question?

- Responses in parts (a)(i–iii) were related to Science Practice 5 Data Analysis and required interpretation of a graph. In part (a)(i) most students were able to identify the highest methane concentration. This required students to read a data point as well as the axis labels from the graph. In part (a)(ii) students were often able to describe the relationship between the two variables in the graph. This required students to recognize that as distance to a fracking well increased, the methane concentration decreased. In part (a)(iii) most students identified the minimum safe distance for a new water well from a fracking well. This required students to describe what the data implied regarding the environmental issue of methane concentration in well water.

- Responses in parts (a)(iv–v) required content knowledge from Topic 6.5 Fossil Fuels. In part (a)(iv) students often had difficulty explaining how fracking fluid is used to access oil and natural gas. Most students described that the fracking fluid released oil and natural gas, but did not describe how the fluid reached the sedimentary rock and that highly pressurized fluid would be needed to open rock fissures containing the oil. In part (a)(v) many students were able to identify a negative geologic effect. Some students identified negative effects other than geologic effects.

- In part (b)(i) many students had difficulty identifying the environmental concept of the Tragedy of the Commons illustrated by the description of the use of groundwater for fracking as individuals using a shared resource for their own self-interest. In part (b)(ii) students had difficulty describing an environmental problem that may result from increased use of groundwater for fracking in arid and semiarid regions. Some students described groundwater depletion but did not tie the concept to an environmental problem such as desertification or springs drying up. In part (b)(iii) students who earned a point were able to describe how the overuse of coastal groundwater resulted in water unsuitable for human consumption. Students who did not earn the point often only identified the process of saltwater intrusion, but did not describe saltwater as contaminating the aquifer.
- In part (c)(i) many students were able to make a claim for a governmental action to improve air quality by reducing the consumption of oil. Some students did not identify a realistic government action. Students who did not correctly identify a realistic government action could not earn the justification point for another environmental advantage in part (c)(ii). Students who did not earn the justification point often gave an advantage related to slowing global climate change. Students were assessed on Skills 7.E and 7.F in their responses in the context of Topic 7.1 Introduction to Air Pollution, Topic 8.2 Human Impacts on Ecosystems, and Topic 6.3 Energy Conservation.

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 how fracking fluid is used to access oil and natural gas. Many students thought that fracking fluid breaks up the oil rather than creating the tiny fissures in the sedimentary rock.	• "Fracking fluid is a mixture of chemicals and sand that is pumped into the fracking well at high pressure. The fluid cracks the sedimentary rock and the sand goes into the cracks to keep them open until the gas/oil can be extracted." • "Fracking fluid is pumped at high pressure to fracture sedimentary rock with oil and natural gas deposits in order to release it."
• Students had difficulty identifying consequences from fracking that would be considered geologic effects. Many students misidentified contaminated groundwater and soil degradation as geologic effects.	• "Hydraulic fracking increases seismic activity." • "One negative geologic effect of hydraulic fracking is that it can cause earthquakes."
• A common misconception was that increased use of groundwater for fracking would cause droughts in arid and semiarid areas.	• "The use of groundwater in arid/semiarid regions could cause desertification in those areas. The groundwater is used to support local water systems like lakes and streams. Taking the groundwater away could lead to those water systems drying up, leading to the death of vegetation and increased soil erosion." • "One environmental problem that may result from increased use of groundwater is that springs and natural pools that form for animals to drink from will dry out. The groundwater fuels these springs, so these springs will run dry, leading to many animals dying from dehydration and decreasing overall biodiversity in the region."

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

- Remind students of the differences required by the task verbs found in the question. "Identify" requires a very short response and does not require additional description or an explanation for a point. On the other hand, students should have practice explaining concepts and answers in preparation for the more detailed answer required from an "explain" task verb. The use of card sorts with descriptive terms for the main steps in the various methods used to extract fossil fuels is an easy way to build student competency for part (a)(iv). Task verbs are described on page 227 of the CED.

- Emphasize to students when identifying a value from a graph, the number must include correct units from the graph axis to earn a point. Also, prompts that ask for "minimum" or "maximum" readings from a graph require a single point, responses that provide a range of points would not earn a point.

- Continue to give students practice interpreting multiple types of graphs as well as describing relationships between variables within graphs. The "Identify and Interpret (I2) Strategy" is an excellent scaffolding activity to use in the classroom.

- Include biomes in discussions of environmental problems and solutions during later units in preparation for Skills 1.C and 7.E where students are asked to explain environmental concepts, "in applied contexts," or for question prompts that include qualifiers such as "in arid or semiarid regions."

- Some students do not read the question prompt carefully and miss exclusions such as "other than slowing global climate change," and then include the excluded content in their response, failing to earn the point. Include exclusions or qualifiers in practice free-response questions.

- Students should understand the difference between solutions proposed by individuals and governments. Provide students opportunities to practice the process of "making a claim about a realistic government action" such as "if the government funded more renewable energy projects then there would be less of a need for energy produced by fossil fuel combustion. This will in turn reduce the amount of oil burned, improving air quality." A claim that proposes "use more public transportation to reduce oil consumption and improve air quality" does not represent a government action.

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

- Teachers will find sample student responses for this question 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 the question was scored and to work with students to help practice writing correct responses.

- Teachers will find scoring guidelines for this question explaining how the question was scored 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.

- Teachers can have students practice with the examples of FRQ 2 on the released 2021 and 2022 AP Environmental Science Exams found on the exam information page on AP Central. Student samples and scoring guidelines are also available for those questions.

- Teachers can have students practice, score, and review the examples of FRQ 2 found on the three AP Environmental Science Practice Exams that can be accessed in AP Classroom.

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Question 3

Task: Analyze an Environmental Problem and Propose a Solution doing Calculations
Topic: Impacts of Urbanization and Solar Radiation and Earth's Seasons
Max Score: 10
Mean Score: 2.67

What were the responses to this question expected to demonstrate?

The intent of this question was for students to demonstrate an understanding of mathematical routines and to provide an environmental solution to a given problem. Students were expected to convey an understanding of urbanization and the use of solar panels in electricity generation.

In part (a) students were expected to demonstrate an understanding of the effects of urbanization on temperature [Practice 1 Concept Explanation and Topic 5.10 Impacts of Urbanization]. In part (b) students were tasked with proposing a solution to help lower the temperature caused by urban heat islands. The task aligns with Practice 7 Environmental Solutions. Finally, students were asked to justify the solution proposed by providing one additional benefit other than reducing temperatures in urban heat islands. This aligns with Practice 7 Environmental Solutions.

In part (c) students were asked to do calculations related to solar panels [Topic 6.8 Solar Energy and Practice 6 Mathematical Routines]. Students were tasked with calculating the percent change in efficiency of solar panels. Next students were tasked with calculating the change in electricity costs for one year based on changes in costs per kWh. Finally, the students were tasked with calculating how many kWh can be produced by a solar panel system in one year.

In part (d) students were asked to explain the seasonal relationship between solar energy and Earth's hemispheres. This task aligns with Topic 4.7 Solar Radiation and Earth's Seasons and Practice 1 Concept Explanation.

How well did the responses address the course content related to this question? How well did the responses integrate the skills required on this question?

- In part (a) student responses earned a point by properly describing how the effect of urbanization [Topic 5.10 Impacts of Urbanization] can lead to the formation of urban heat islands in several ways. Students earned a point by describing how low albedo surfaces absorb more of the Sun's energy increasing temperatures, by describing how buildings can block wind currents causing increasing temperatures, by describing how cutting down trees results in less shade causing increasing temperatures, or by describing how waste energy within the city can lead to an urban heat island.

- In part (b)(i) students were assessed on Practice 7 Environmental Solutions and Topic 5.10 Impacts of Urbanization. Students who earned a point often proposed planting more trees over dark roads or in parks thus creating shade. Other students earned points by stating that painting surfaces within the city a lighter color will increase the albedo of the surface and reduce the amount of heat absorbed. Students also wrote about decreasing the use of systems, like vehicles, that produce heat in the urban environment. In (b)(ii) students' responses justified their response in (b)(i) [Practice 7 Environmental Solutions]. Students earned points by providing that planting more trees would increase habitat for wild animals, reduce CO_2 levels, reduce urban runoff or flooding [Topic 5.13 Methods to Reduce Urban

Runoff], or provide some benefit for humans in the urban environment. Points were earned for providing that coloring dark surfaces white will also decrease costs of cooling buildings.

- In part (c) many students worked systematically and earned a significant number of points out of the six points available; this task aligns with Practice 6 Mathematical Routines. In part (c)(i) students demonstrated the ability to calculate a percent change in efficiency of solar panels. In part (c)(ii) points were earned for calculating the change in electricity costs for a homeowner. And in part (c)(iii) students used dimensional analysis to calculate the power generated by sample solar panels. Units canceled nicely and therefore could be used to lead students to correct responses through dimensional analysis.

- In part (d) students used their understanding of Topic 4.7 Solar Radiation and Earth's Seasons to explain how the tilting of the Northern Hemisphere toward the Sun caused more direct solar energy or longer days than in the Southern Hemisphere.

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

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
• Students described the urban heat island as caused by global climate change. Students also proposed solutions related to global climate change.	• "Urbanization creates large stretches of black asphalt, which absorb heat and heat up the surrounding area making a heat island." • "Rooftop gardens can cover otherwise black roofs with a higher albedo material that will absorb less heat."
• Students did not show the steps required to earn points for the setup for the calculation problems. Students did not earn credit when leaving out units in answers.	• $30 \text{ panels} \times \frac{300 \text{ watt}}{1 \text{ panel}} \times \frac{1 \text{ kW}}{1{,}000 \text{ watts}} \times \frac{4 \text{ hours}}{1 \text{ day}} \times \frac{365 \text{ days}}{1 \text{ year}}$ • 13,140 kWh
• Students explained the Northern Hemisphere as being closer to the Sun from June–August and is what causes it to be warmer. Students incompletely described how the tilt of Earth causes an increase in solar radiation.	• "During June and August, the Earth is tilted towards the sun, making the light that hits the Northern Hemisphere more concentrated, than it is in the Southern Hemisphere."

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

- Remind students of the differences required by the task verbs found on the exam (pg. 227 of the CED). "Identify" requires a very short response and does not require an explanation for a point. On the other hand, students should have practice explaining concepts and answers in preparation of the more detailed answer required from an "explain" task verb.

- Students should evaluate AP Environmental Science exam calculation questions throughout the year. Students should be comfortable with dimensional analysis involving several different unit conversions. If a performed calculation is not fully correct, then that calculation is wrong and the point will not be earned.

- Students should be comfortable making percent change calculations, including showing the "x 100" step in the setup.

- Students should learn to answer the question or respond to the prompt as presented.

- Students should not use drawings as their explanation or description of a concept.

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

- Teachers will find sample student responses for this question 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 the question was scored and to work with students to help practice writing correct responses.

- Teachers will find scoring guidelines for this question explaining how the question was scored 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.

- Teachers can have students practice with the examples of FRQ 3 on the released 2021 and 2022 AP Environmental Science Exams found on the exam information page on AP Central. Student samples and scoring guidelines are also available for those questions.

- Teachers can have students practice, score, and review the examples of FRQ 3 found on the three AP Environmental Science Practice Exams that can be accessed in AP Classroom.

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