Chief Reader Report on Student Responses:

2024 AP® Environmental Science Set 1

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: Stream Ecosystem BOD diagram
Max Score: 10
Mean Score: 4.72

What were the responses to this question expected to demonstrate?

The intent of this question was for students to demonstrate their ability to interpret an oxygen sag curve diagram. Students were asked to describe the effects of point–source pollution on dissolved oxygen levels and macroinvertebrate species biodiversity in a stream. Students were also asked to explain how persistent organic pollutants are passed through a food web in an ecosystem. The question included elements of experimental design, where students were asked to state a hypothesis, describe a reason for using an experimental control, and identify the dependent variable from an experiment.

In parts (a–c) students were asked to use information from the oxygen sag curve diagram to identify the area with the lowest levels of dissolved oxygen, describe the relationship between biological oxygen demand and dissolved oxygen, and identify where there is likely point-source water pollution discharged into the stream [Science Practice 2 Visual Representations and Topics 8.1 Sources of Pollution and 8.2 Human Impacts on Ecosystems].

In parts (d–f) students were asked to read a brief passage about a scientific investigation into the relationship between dissolved oxygen levels and macroinvertebrate species richness in the stream. Students were then asked to identify the dependent variable for the researchers' investigation, identify a testable hypothesis for the researchers' investigation, and describe the reason the researchers selected zone A to serve as the control in the investigation [Science Practice 4 Scientific Experiments].

In part (g) students were asked to explain how the modification to collect data in the winter months could affect the results of the investigation [Science Practice 4 Scientific Experiments and Topic 2.4 Ecological Tolerance]

In part (h) students were asked to describe the effect that the introduction of raw sewage into the stream could have on the population of bacteria in the stream [Science Practice 7 Environmental Solutions].

In part (i) students were asked to identify an abiotic factor other than dissolved oxygen and organic pollution that could also influence the population size of bacteria in the stream [Science Practice 1 Concept Explanation and Topic 3.5 Population Growth and Resource Availability].

In part (j) students were asked to explain how persistent organic pollutants can affect higher trophic levels in aquatic food webs [Science Practice 1 Concept Explanation and Topics 8.7 Persistent Organic Pollutants and 8.8 Bioaccumulation and Biomagnification].

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 were able to apply Science Practice 2 Visual Representations and correctly identify Zone C as the zone with the highest level of dissolved oxygen.
- In part (b) students were able to indicate an inverse relationship between dissolved oxygen and biological oxygen demand, and/or describe in a variety of ways that as biological oxygen demand

increases, dissolved oxygen decreases. Stating that it was an inverse relationship without a description did not earn a point in part (b).

- In part (c) most students were able to interpret the data on the graph and correctly identify Zone B as the zone where there is likely point-source water pollution discharged into the stream.
- In part (d) correct responses applied Science Practice 4 Scientific Experiments to identify "the number of macroinvertebrate species" or "macroinvertebrate species richness" as the dependent variable in the experiment. Some students incorrectly identified dissolved oxygen as the dependent variable, while other responses indicated "number of macroinvertebrates" which did not earn the point.
- In part (e) most students were able to successfully identify a testable hypothesis for the researchers' investigation. Responses did not have to present a "correct" hypothesis to earn a point. The most common responses earning a point indicated that as dissolved oxygen increased, macroinvertebrate species diversity would also increase.
- In part (f) responses that earned a point correctly described that Zone A was selected as the control in the investigation because it was upstream of, or unaffected by, the likely location of point-source pollution.
- Responses in part (g) earned the point by explaining that winter months would have lower water temperatures, which would have higher levels of dissolved oxygen. Increased dissolved oxygen would then increase the number of species. Other responses earning the point explained that less sunlight in the winter months would lead to lower rates of photosynthesis, which would lower dissolved oxygen, thus lowering the number of species.
- Students who earned a point in part (h) most often described an increase in the bacteria population because bacteria feed on the nutrients/organic matter in the sewage.
- In part (i) most students were able to correctly identify an abiotic factor other than dissolved oxygen and organic pollution that could influence the population size of bacteria in the stream. Common correct responses included "sunlight," "temperature," and "sediment."
- In part (j) students were asked to explain how persistent organic pollutants can affect higher trophic levels in an aquatic food web. Correct responses generally referred to the process, impacts, or properties of biomagnification [Topic 8.8 Bioaccumulation and Biomagnification]. Students were challenged by this part of the question because responses that focused on the process of biomagnification needed to include both the uptake by lower trophic-level organisms, and consumption by higher trophic-level organisms.

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

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
• In part (e), some students incorrectly wrote their hypothesis in the form of a scientific question, while others wrote the hypothesis starting with the dependent variable.	• "As dissolved oxygen levels increase, the number of macroinvertebrate species will also increase."
• In part (g), students struggled to explain how the modification would affect the results of the experiment. Many students wrote partially correct answers about the relationship between colder water temperatures and higher dissolved water temperatures, but did not include an impact on species richness.	• "Due to colder water temperatures, the dissolved oxygen levels would increase, which would help to increase the species richness of macroinvertebrates."
• In part (j), students had difficulty explaining the concept of biological magnification of persistent organic pollutants in the food web. Some students wrote partially correct answers when they identified that persistent organic pollutants biomagnified in the food web, but failed to explain the concept or impacts of biomagnification.	• "Persistent organic pollutants can bioaccumulate in organisms which consume them, as the organism's body has no way of processing or removing them from the body. …Predators consume more of their contaminated prey, and as a result have higher levels of pollutants in their bloodstream."

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.

- Introduce the task verbs used in the exam early in the school year, then frequently use them in both formative and summative student assessments. "Identify" questions can be answered with only a few words or a short phrase and require no further description. The "describe" task verb requires student to provide the relevant characteristics of a specified topic and requires more information to earn a point. The "explain" task verb asks students to articulate the relationship between relevant variables in a relationship, process, pattern, situation, or outcome.

- Give students regular opportunities to interpret diagrams and graphs during class activities and assessments to build their skill level in Science Practice 2: Analyze visual representations of environmental concepts and processes.

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.
- The AP Environmental Science Online Teacher Community offers many resources, discussions, tips, and activities that 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 incorporate the laboratory exercises that are 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 AP 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:

- 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 discussion of task verbs.
- 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, including application of task verbs, 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.

- 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.

- Participate in a workshop on project-based learning (PBL). The College Board offers workshops for teachers interested in using AP Environmental Science PBL modules as well as year-long support for implementation. For more information, visit https://apcentral.collegeboard.org/professional-learning or contact approjectbasedlearning@collegeboard.org.

Question 2

Task: Analyze an Environmental Problem and Propose a Solution
Topic: Mealworm Protein Graph
Max Score: 10
Mean Score: 3.91

What were the responses to this question expected to demonstrate?

This question focused broadly on the environmental impacts from meat production and other agricultural practices as well as the impacts of climate change on crop production.

In part (a) students were asked to analyze data from a graph to identify the amount of land use required to produce one kilogram of chicken protein [Science Practice 5 Data Analysis and Topic 5.7 Meat Production Methods].

In part (b) students were asked to demonstrate knowledge by identifying the type of survivorship curve exhibited by an r-selected species [Science Practice 1 Concept Explanation and Topics 3.2 K-Selected r-selected Species and 3.3 Survivorship Curves].

In part (c) students were asked to explain why the reproductive strategy of an r-selected species would be an advantage for using the larvae of that species as an alternative protein source to sustain a growing human population [Science Practice 1 Concept Explanation and Topics 3.2 K-Selected r-selected Species, 3.8 Human Population Dynamics, and 5.12 Introduction to Sustainability].

In parts (d) and (e) students were asked to extract data from graphs to explain unique environmental impacts from producing protein from different animals [Science Practice 5 Data Analysis and Topics 5.7 Meat Production Methods and 9.3 The Greenhouse Effect].

In part (f) students were asked to describe how water quality can be altered by cattle grazing near a stream or river [Science Practice 7 Environmental Solutions and Topics 5.7 Meat Production Methods, 8.2 Human Impacts on Ecosystems, and 8.5 Eutrophication].

In part (g) students were asked to propose a solution to reduce negative impacts on waterways that result from cattle grazing, while still allowing cattle to graze [Science Practice 7 Environmental Solutions and Topics 5.7 Meat Production Methods and 5.15 Sustainable Agriculture].

In part (h) students were asked to describe a sustainable agricultural practice used to reduce soil erosion [Science Practice 7 Environmental Solutions and Topic 5.15 Sustainable Agriculture].

In part (i) students were asked to provide an additional benefit of the proposed sustainable agricultural practice, other than the reduction of soil erosion [Science Practice 7 and Topics 4.2 Soil Formation and Erosion and 5.15 Sustainable Agriculture].

In part (j) students were asked to describe how climate change could negatively affect crop production [Science Practice 7 Environmental Solutions and Topic 9.5 Global Climate Change].

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) students were highly successful at identifying the appropriate graph needed to report a requested data point correctly (Science Practice 5 Data Analysis).

- In part (b) correct responses identified Type 3 or Type III as the survivorship curve associated with r-selected species.

- In part (c) correct responses explained that darkling beetles reproduce quickly/frequently, or generate many offspring during each reproductive cycle, which enables production of a large amount of protein sufficiently fast to support needs of a growing human population.

- In part (d) correct responses interpreted data from two graphs for comparative analysis to help explain that production of chicken protein is less harmful to the environment than an equal mass of pork protein due to lower global warming potential, or due to lower land use which preserves habitats, or reduces fossil fuel use and erosion.

- In part (e) correct responses interpreted data from two graphs and incorporated information about methane emissions to help explain that production of beef protein will have a different impact on global warming than an equal mass of mealworms, chicken, and pork protein. Students were expected to incorporate the high global warming potential of methane in their response. However, student responses that cited loss of habitat due to beef production were accepted if the response also articulated the connection between habitat loss and release of CO_2 or reduction in carbon storage.

- In part (f) correct responses described how cattle grazing alters water quality by contributing to erosion and higher sediment inputs, or through their feces, the cows add nutrients or bacteria.

- In part (g) correct responses proposed solutions to reduce impacts of cattle grazing on waterways, most often by suggesting fences be built to exclude cattle from the riparian zone or implementing rotational grazing strategies. Other correct responses were eating less beef or providing alternative water sources to cattle.

- In part (h) correct responses described sustainable agricultural practices that would help reduce soil erosion such as implementation of no-till farming, planting windbreaks, terrace farming, contour plowing, or intercropping.

- In part (i) correct responses justified the use of the agricultural practice described in part (h) by providing an additional advantage of that practice, other than preventing soil erosion. Depending on the response in (h), correct responses included reduced operation costs to farmers, reduced fuel use, increased groundwater recharge, carbon stored in soil, added nutrients to soil, or preserved habitat.

- In part (j) correct responses most frequently described how crop yields would decline as increased temperatures, droughts, floods, or extreme weather events caused by climate change led to increased mortality of crop plants. Some students correctly described how climate change could cause conditions to shift outside the range of tolerance for crop species, or that the geographic range of crop pests or invasive species could expand because of climate change to negatively impact crop yields.

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 were frequently unable to correctly identify that r-selected species have a Type 3 survivorship curve.	• "The darkling beetle exhibits a Type III survivorship curve."
• In part (c) students often correctly described the characteristics of r-selected reproductive strategy but were unable to explain why those characteristics would be advantageous in the applied context specified.	• "The reproductive strategy of darkling beetles is an advantage for humans because they reproduce quickly and have a lot of offspring at one time, meaning they can provide an abundant and consistent source of protein for humans quickly."
• Students demonstrated several misconceptions about methane. Many students implied that methane was something other than a gas, suggesting it is a toxin that washes into streams like a particulate. Many students seemed to think that cows only emit methane in their feces or only as part of the slaughtering process. There are also misconceptions that methane contributes significantly to global warming because it causes damage to the ozone layer, rather than because it is a potent greenhouse gas.	• "Methane produced from fermentation in cow's digestive system is a stronger greenhouse gas than CO_2 so the global warming potential from cows is a lot higher than the animals that don't emit methane."
• Students do not know the primary purpose and associated benefits of individual sustainable agricultural practices, and often confuse or conflate different practices with one another.	• "The use of no-till farming doesn't break apart the soil and make it loose so it is more resistant to eroding away in runoff."
• Students struggled to differentiate between pasture grazing and industrial-scale meat production (e.g. CAFOs). They also displayed a similar knowledge gap for industrial-scale agriculture.	• "A solution would be to rotate or temporarily relocate the cattle to other grazing fields to allow the grass to grow back and allow the roots and soil to be maintained."

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?

- When presenting survivorship curves (Topic 3.3), consider reviewing characteristics of r-selected and K-selected species concurrently (Topic 3.2). Showing students how the three curve types are generated (or having them practice drawing their own survivorship curves) may help them better understand the underlying dynamics illustrated by the curves. This, in turn, should help clarify why r-selected and K-selected species are expected to have different types of survivorship curves.

- When covering greenhouse gas emissions (Topic 9.3), emphasize the different characteristics of principle greenhouse gases. Students need to have a clear understanding of the distinct roles of different atmospheric gases with respect to both climate change (Topics 9.4, 9.5) and ozone depletion (Topic 9.1).

- Provide students ample opportunity to interact with data and engage in Science Practices 5.C, 5.D, and 5.E. This will help students move beyond describing patterns and relationships in the data, so they can draw conclusions (Practice 5.C), interpret results (Practice 5.D) and explain what the data implies or illustrates about environmental issues (Practice 5.E).

- When covering agriculture (Unit 5), make sure students are familiar with the scale of different types of agricultural practices. Include real-world examples for students to consider and analyze. This will help students understand the feasibility and likely effectiveness of proposed solutions to environmental problems.

- Remind students to read each part of the FRQ carefully and respond in a way that clearly answers the question being asked. Also, each part of the FRQ is independent so student responses do not have to be a continuation or contain a transitional link from the previous part(s), unless the question specifies otherwise.

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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- 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 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 interpretation of 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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- 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 3

Task: Analyze an Environmental Problem and Propose a Solution Doing Calculations
Topic: Energy Production and its environmental impacts
Max Score: 10
Mean Score: 4.35

What were the responses to this question expected to demonstrate?

The intent of this question was for students to demonstrate an understanding of concepts related to electricity generation [Topic 6.3 Fuel Types and Uses], math skills related to energy [Science Practice 6 Mathematical Routines and Topic 6 Energy Resources and Consumption], and advantages of forests [Topic 5 Land and Water Use].

In part (a) students were expected to demonstrate understanding of how electricity is generated in nuclear power plants [Science Practice 1 Concept Explanation and Topic 6.6 Nuclear Power].

In part (b) students were required to describe how using water in cooling towers of a nuclear power plant can have negative impacts on nearby bodies of water [Science Practice 7 Environmental Solutions and Topics 6.6 Nuclear Power and 8.6 Thermal Pollution].

In part (c) students were asked to calculate the amount of electricity that was generated at nuclear power plants from a given total electrical energy production and a given percent that was generated at nuclear power plants [Science Practice 6 Mathematical Routines and Topic 6.6 Nuclear Power].

In part (d) students were expected to demonstrate understanding of the impacts on air quality by switching from coal power plants to natural gas power plants [Science Practice 7 Environmental Solutions and Topics 6.3 Fuel Types and Uses, 7.4 Atmospheric CO_2 and Particulates, and 7.7 Acid Rain].

In part (e) students were asked to justify the advantages of planting large areas with trees, excluding the reduction of atmospheric greenhouse gasses [Science Practice 7 Environmental Solutions and Topics 5.17 Sustainable Forestry, 4.2 Soil Formation and Erosion, and 2.2 Ecosystem Services].

In parts (f) and (g) students were expected to calculate answers associated with energy consumption and production. In part (f) students were asked to calculate how many homes could be provided with electricity from a given amount of natural gas that had been extracted [Science Practice 6 Mathematical Routines and Topic 6.2 Global Energy Consumption]. In part (g) students were required to calculate how much less CO_2 would be produced if all coal power plants were converted to natural gas [Science Practice 6 Mathematical Routines and Topics 6.3 Fuel Types and Uses and 6.5 Fossil Fuels].

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 demonstrated knowledge about the effects of electrical generation from fossil fuel and nuclear power plants on the environment, including impacts to nearby bodies of water from the use of water in cooling towers and the impacts to air quality. Students demonstrated the advantages of large-scale planting of trees. Students were expected to be able to set up and evaluate basic calculations, showing correct numeric values and arithmetic operations, and report answers with correct units, when required.

- In part (a) many students identified Uranium as the fuel used in nuclear power plants. Some responses included the isotope Uranium-235.
- In part (b) many students described thermal pollution and its effect on decreased dissolved oxygen levels as a negative environmental impact on nearby bodies of water from cooling towers at nuclear power plants.
- In part (c) students calculated the amount of electricity produced in the United States in nuclear power plants. Some students used unit cancellation while others set up proportions and cross multiplied to calculate the correct set up and answers.
- Responses in part (d) correctly stated that switching from coal to natural gas power plants could improve air quality by reducing amounts of particulates, ash, or SO_2 released with the burning of natural gas as compared to coal.
- In part (e) students justified the proposal for large-scale tree planting by explaining that forests provide habitats for many different species, help reduce erosion, and create a more aesthetically pleasing environment.
- In part (f) students calculated how many homes could be provided electricity by the natural gas extracted from a large deposit. Many students were able to correctly utilize scientific notation and use unit cancellation to get correct setup and answers.
- Most correct responses in (g) used unit cancellation and scientific notation to calculate the difference in CO_2 produced when switching from coal to natural gas power plants. In (g), the prompt did not specify the units of the answer, so students had to identify units attached to the value reported.

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 misconception was that water used in nuclear power plant cooling towers becomes radioactive and will contaminate bodies of water when returned.	• "While uranium is used inside the nuclear reactor the discharge water does not contain radiation but the heated water can still be a concern b/c it lowers DO levels where it is discharged"
• Some responses incorrectly indicated that pollutants such as SO_2 and particulates are greenhouse gases.	• "…coal powered plants release SO_2 which can lead to lower air quality compared to using natural gas power plants"
• A common misconception is that the water or the steam within a nuclear power plant is the fuel that drives the production of electricity.	• "The fuel used in a nuclear power plant is uranium"

• Responses included the misconception that natural gas combustion results in zero emissions.	• "…switching to natural gas power plants from coal power plants will improve air quality because natural gas produces less particulates"

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?

- Reinforce connections between different topics throughout the course. For example, thermal pollution is mentioned in Topic 6.6 (Nuclear Power) and Topic 8.6 (Thermal Pollution). If students are compartmentalizing knowledge, they may not fully understand the connection between these two topics. It may also be important to emphasize the pathways through which radioactive waste can be released from a power plant, for example through accidents (Topic 6.6, ENG-3.H.1) or hazards in long-term disposal of nuclear waste (Topic 6.6, ENG-3.G.3).

- When covering air pollution (Topic 7.1), remember that students often confound the effect of different atmospheric gases. It is important to cross-reference the material and double check that students can accurately distinguish between the effects of greenhouse gases and other types of air pollutants.

- Units in the setup were not required. However, students who did not use unit canceling or dimensional analysis often submitted incorrect mathematical operations and calculated an incorrect value. Teaching students dimensional analysis with units will help students to produce correct values even if the units are not required in the setup on the AP Exam.

- Students often did not correctly use or transcribe the scientific notations in calculation problems. They also could use more support in the use of their calculators and scientific notation. Giving students many opportunities to practice calculations using scientific notation along with providing feedback would prepare students for calculation problems.

- Remind students to read the question carefully and circle or mark what is being asked and what cannot be used. On prompts where it stated "in addition to reducing greenhouse gas emissions" or "other than the reduction of atmospheric greenhouse gases" students incorrectly used those as their answer and did not earn points.

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

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.

- 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.

Resources for enriching content across topics:

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- 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 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 and application of task verbs.
- 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.
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