Chief Reader Report on Student Responses:

2021 AP® Environmental Science Free-Response Questions

- Number of Students Scored 160,771
- Number of Readers 664
- Score Distribution

Exam Score	N	%At
5	11,179	7.0
4	39,998	24.9
3	29,714	18.5
2	44,333	27.6
1	35,547	22.1

- Global Mean 2.67

The following comments on the 2021 free-response questions for AP® Environmental Science were written by the Chief Reader, Michele Goldsmith of Southern New Hampshire 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 and Experiment/Graph	**Topic:** Soil Erosion and Water Sedimentation
	Max. Points: 10	**Mean Score:** 4.10

What were the responses to this question expected to demonstrate?

The intent of this question was for students to demonstrate their ability to identify components of a scientific experiment and to explain concepts related to agricultural practices and soil erosion. Students were expected to convey an understanding of the sedimentation of waterways.

In part (a) students were expected to demonstrate their ability to answer questions about the effect of four common agricultural practices on the annual soil erosion rates at various land slopes based on data provided in a graph [Practice 5-Data Analysis, Practice 1-Concept Explanation, Topic 5.4 Impacts of Agricultural Practices]. In part (b) students were asked to identify and evaluate various parts of an experiment focused on decreasing sediment run-off from disturbed land [Practice 4-Scientific Experiments, Topic 4.2 Soil Formation and Erosion, Topic 8.2 Human Impacts on Ecosystems]. In addition, after being presented with data from the experiment, students were asked to make a claim about a presented hypothesis. In part (c) students were asked to describe the survivorship curve of fish species living in streams affected by sediment [Topic 3.3 Survivorship Curves] and asked to explain the effects of sediment run-off on the reproductive ability of these fish [Practice 7-Environmental Solutions, Topic 8.2 Human Impacts on Ecosystems].

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 content knowledge about soil erosion, agricultural practices, and survivorship curves. In addition, students were expected to interpret a graph and a data table and to describe and identify experimental design components.

- Responses in part (a) were related to Science Practice 5 (Data Analysis) and required the reading and interpretation of a soil erosion graph. In part (a)(i) students additionally used skills from Science Practice 4 (Scientific Experiments) to identify a scientific question that resulted from the data presented in the graph. Many students simply turned the title of the given graph into a scientific question by writing, “What is the effect of percent slope on annual erosion for four agricultural practices?” To earn the point, responses had to be written in question form and had to include all three components of the graph: erosion, slope, and one or more agricultural practices, though these concepts could be written using different terms. In (a)(ii) students determined that “crop rotation” was the agricultural practice that had less than tolerable loss of soil at a 15 percent slope. In (a)(iii) students used the graph to describe that “cover crop plus no till had less soil erosion compared to no till by itself.” The final question in this section, (a)(iv), required students to use content knowledge from Topic 4.2 (Soil Formation and Erosion) to identify a natural mechanism of soil erosion. The most common responses were “rainfall” or “wind.”

- Responses in part (b) were related to the design of the experiment given in the prompt and required students to use skills from Science Practice 4 (Scientific Experiments) to identify different components of the experiment design. In part (b)(i) the dependent variable was most frequently identified as “the amount of sediment run-off.” Part (b)(ii) required students to describe a way to add a control to improve the design of the study, and most responses accurately described a “new plot (Plot C) which would not have any straw bales or planted grass to catch the sediment run-off.” Part (b)(iii) asked for additional variables that were not discussed and could affect the results of the study. Responses either answered this one of two ways. Some responses focused on variables that could affect the conditions between the two given treatments: Plot A (straw bale) and Plot B (planted grass), such as “Plot A could get more

rainfall on it than Plot B." Other responses focused on overall differences in a variable, such as "Some days the amount of rainfall might be bigger or smaller depending on how long the experiment goes on." Both types of answers were accepted, and the most common answers related to the amount of rainfall received and the slope of the plots. The final question (b)(iv) required students to refer to the given hypothesis and make a claim about it using the data in the data table. This required the use of Science Practice 5 (Data Analysis). In addition to this science practice, students had to either use content knowledge from Topic 8.2 (Human Impacts on Ecosystems) to understand how the given data related to water clarity and sediment run-off or use the information given in the prompt to analyze the data. In order to earn this point, the response had to assert that the hypothesis was rejected/not supported/wrong because, according to the data given, the planted grass plots reduced sediment run-off more than the straw bales did. Some responses were able to interpret the data accurately but did not make a claim about the given hypothesis and, therefore, did not earn the point.

- Part (c) of the question pivoted and asked students about fish that live in the stream into which this sediment flows. Part (c)(i) required students to use information in Topic 3.3 (Survivorship Curves) to describe the curve found in these fish. Most responses had inaccurate descriptions of a Type I or a Type II curve. The accurate curve (Type III) was often not completely described and only included information on the early life stage such as "high infant mortality" rather than focusing on the entire life cycle. A complete response included information describing that few individuals from this population reach reproductive maturity and adulthood. The final part of this question (c)(ii) asked students to explain the impact on fish reproduction of sediment that runs into a stream. As part (c)(ii) requires an explanation, a correct response had three parts. Responses had to describe the effect of the sediment on the fish habitat, then they had to explain the impact of this effect on the habitat, and finally, they had to explain the impact on the reproduction of the fish that lived in that stream. Many responses did not adequately explain how the sediment negatively affected the reproduction of the fish. Some acceptable impacts were egg death, egg suffocation, and decrease in numbers of eggs laid. Answers of "can negatively affect reproduction of fish" were not accepted as that statement is found in the prompt. Responses could either focus on the impact on the eggs or on the parent fish as they are preparing to lay eggs. An example of this would be "sediment into the stream makes the water cloudy or turbid, which means the fish's gills get clogged with sediment which stresses the fish and makes them too weak to lay eggs." Responses must directly negatively impact the fish, so answers that focused on eutrophication or plant death were not accepted. The information used to answer part (c)(ii) is found in Topic 8.2 (Human Impacts on Ecosystems).

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 interpret turbidity data using the information given in the stem of the question. The stem reads, "Turbidity can be determined by measuring the depth at which a submerged object can no longer be seen from the surface." The turbidity data was given in centimeters, and students had to analyze the data to interpret that a deeper visualization (higher number of centimeters) meant less sediment run-off/more clarity.	• "The planted grass plot led to higher turbidity indicating clearer water with less sediment run-off." • "planted grass had more centimeters of depth which means the water had more clarity than straw bales which suggests less runoff is coming from the plot with planted grass."

• A common misconception was that r-selected is a type of survivorship curve. The prompt asks students to "Describe the type of survivorship curve expected for these fish species." Students would misidentify the type of survivorship curve as: r-selected, Type I, or Type II. This was a describe, not identify question, and students frequently described the fish as laying hundreds of eggs with only a few hatching. They did not describe survivorship through the entire lifespan of the fish. In addition, descriptions frequently veered off into explaining the lack of parental care or short lifespans.	• "The survivorship curve would likely be a type 3 where many fish eggs are laid, and many fish die early on with only a few surviving to adulthood."

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 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 more basic concept of scientific questions.
- The skills in Science Practice 4 and 5 ask students to interpret data and graphs. These skills should be practiced often in the classroom, so students are comfortable making these interpretations and analyses. Weekly low-stress, minimal time-required graph analysis can build these skill sets and student comfort levels. Many teachers find current graphs in newspapers and online sources to give students practice.
- Often population reproduction strategies such as r-strategist and K-strategist are taught at the same time as population survivorship curves. Clearly distinguish between these two population dynamic measurements, so students understand the nuances of each.
- Some students spend time during the exam drawing unlabeled graphs to support the answer. These unlabeled graphs do not detract from their response but are not considered when grading the response. These are not an effective use of exam time.

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 FRQ 1 from the second set of released FRQs from the 2021 exam found on the exam information page on AP Central. Student samples and scoring guidelines are also available for that question.

- 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.
- 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:** Diagram **Topic**: Global Amphibian Biodiversity and Endangered Species

Max. Points: 10 **Mean Score:** 3.85

What were the responses to this question expected to demonstrate?

The intent of this question was for students to demonstrate their ability to evaluate a diagram of the global distribution of amphibian species, discuss threats to biodiversity, and identify and explain ways to protect endangered species.

In part (a) students were asked to identify and describe regions with high amphibian biodiversity [Practice 2-Visual Representations, Topic 1.2 Terrestrial Biomes, Topic 2.1 Introduction to Biodiversity] based on information on a map of the global distribution of amphibian species. In part (b), students were asked to describe an anthropogenic reason for deforestation [Practice 7-Propose and justify solutions, Topic 5.1 The Tragedy of the Commons] In part (c) students were asked to identify and describe threats to amphibian biodiversity and biodiversity in general [Practice 1-Concept Explanation, Topic 2.1 Introduction to Biodiversity, Topic 9.10 Human Impacts on Biodiversity]. In part (d) students were asked to identify and explain one environmental law relevant to the protection of endangered species that is used to solve environmental problems [Practice 7-Environmental Solutions, Topic 9.9 Endangered Species]. Finally, in part (e), students were asked to propose and justify a viable solution for a case study involving real estate development in a wetland that is home to a native frog species [Practice 7-Environmental Solutions].

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 part (a) were related to Science Practice 2 (Visual Representations) and required the reading and interpretation of a world map. In part (a)(i) most students were able to identify the range with greatest richness. This required students to differentiate between latitude and longitude and to understand the concept of "range." In (a)(ii) students were often able to identify the biome from the map. In (a)(iii) most students described that the area was warm and humid year-round and that these were ideal conditions for amphibians to thrive. Part (a) responses required content knowledge from Topic 2.1 Introduction to Biodiversity and Topic 1.2 Terrestrial Biomes.

- In part (b) students who earned a point often linked the expanding human population as cause for deforestation through a variety of processes, including agriculture, housing, and products.

- In part (c)(i) students often had difficulty explaining the connection between species richness and environmental stressors. Some students described trophic cascades or genetic diversity, but they did not tie the concept back to the ecosystem. In part (c)(ii), many students were able to explain why amphibian biodiversity is declining. Students who did not earn the point often only identified but did not explain why biodiversity is declining globally.

- In part (d) many students answered with the Endangered Species Act and CITES and could then explain how the legislation protected species threatened by extinction. Some students identified a piece of legislation that was not designed to protect species threatened by extinction. Students who did not correctly identify legislation could not earn the explain point in part (d)(ii). Part (d) responses evaluated Skill 7, where students had to describe potential responses or approaches to environmental problems.

- In part (e) most students discussed protecting the wetland or using a setback to reduce the impact of development on the frog species. They then correctly justified this solution by linking the action to increased flood control or preventing contamination in wetlands. Students who discussed tourism in (e)(ii) did not earn a point, as tourism would degrade the area that was designed to protect the frog species and was not intended for human activities. Students were assessed on Skill 7E and 7F in their responses in the context of Topic 9.10 Human Impacts on Biodiversity.

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

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
• Problems identifying latitudinal ranges on a map of the world. Many students identified a single latitude, rather than a range.	• "The greatest amphibian species richness is located between 30° north and 30° south of the equator."
• Differentiating between types of rainforest. Some students only responded by saying "rainforest." Need to differentiate between tropical and temperate rainforests.	• "This range most likely represents the tropical rainforest biome."
• Students commonly had difficulty explaining the link between species richness and the response of an ecosystem to environmental stressors.	• "A high species richness enables an environment to remain stable following/during environmental stressors. With an abundance of varying species with varying niches, if one aspect of the environment changes and one species is no longer adapted, a new species fills in the gap."

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?

- Reinforce the difference between the various task verbs used on the exam (p. 227 of the CED). Students generally did a good job responding to the Identify and Describe task verbs, but some struggled to fully complete the requirements for the Explain and Justify task verbs. Understanding the increasing level of detail and thought required by each of these task verbs will help students develop problem-solving skills, as well as improve their performance on the exam. Teacher might consider using the task verbs on class assignments, so students have many opportunities to practice responding to these task verbs.
- Make sure that students get experience with map reading, as well as placement of the major terrestrial biomes on the map. Given the global scope of this class, students should be presented with learning activities that include maps. From biome activities to activities about Earth's seasonality, there are

opportunities throughout the curriculum where maps (and other visual representations) can and should be included in the learning activities.
- Continue to emphasize the detailed ways that human actions negatively impact other species.
- When describing/discussing environmental phenomena, make sure to emphasize the importance of directionality with your students. It is not sufficient to say something changes, challenge them to identify the directionality of the change, for example, that "population is increasing" instead of merely saying there is a change in the population size.
- Students should be knowledgeable about the "Required Environmental Legislation" (p. 26 of the CED). At a minimum, students should know the correct name and description of each piece of legislation, as well as the application of the legislation to solutions for environmental problems.
- Teachers should practice the process of developing solutions to environmental problems with students. Proposing and justifying a viable plan of action requires a great deal of knowledge about functioning ecosystems, as well as the knowledge of how we plan for and implement environmental mitigation and remediation.

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 FRQ 2 from the second set of released FRQs from the 2021 exam found on the exam information page on AP Central. Student samples and scoring guidelines are also available for that question.
- 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:** Calculations **Topic:** Coal-fired and Natural-gas Power Plant with Calculations

Max. Points: 10 **Mean Score:** 2.93

What were the responses to this question expected to demonstrate?

The intent of this question was for students to demonstrate their ability to describe nonrenewable energy sources and compare coal and natural gas electricity generation. Students were expected to show their work and complete calculations related to air pollution/particulate pollution.

In part (a) students were expected to demonstrate an understanding of nonrenewable energy sources [Practice 1-Concept Explanation, Topic 6.1 is Renewable and Nonrenewable Energy]. In parts (b) and (c) students were asked to describe an environmental and an economic advantage of replacing a coal-fired powerplant with a natural-gas power plant [Practice 7-Environmental Solutions, Topic 6.3 Fuel Types and Uses]. In part (d) students were asked to propose a solution to reduce the incidence of carbon monoxide poisoning in humans. In parts (e), (f), and (g), students were asked to calculate the percent change of an air pollutant over a particular time period, the amount of particulate pollution reduction by leaf deposition, and the increase in the number of hospital admissions due to an increase in particulate pollution. The calculation portions of the question evaluated understanding and application of Science Practice 6 Mathematical Routines [Topic 7.1-Introduction to Air Pollution].

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 be knowledgeable about the qualities, advantages, and disadvantages of two different fossil fuels and also to propose a solution to a problem that may arise from the residential use of one of those fossil fuels. Students were expected to set up and then evaluate basic calculations concerning the change in and effects of particulate air pollution.

- In part (a) student responses earned a point by properly describing a nonrenewable energy resource as being finite or limited by using the descriptors “finite” or “limited” within their response. Students also successfully compared the rate of formation of a nonrenewable energy resource to the rate of its consumption by stating that “coal takes millions of years to form while we burn a lot of it very quickly”.

- In part (b) student responses earned a point by properly describing an environmental advantage of burning natural gas rather than coal as “less greenhouse gases” or “less CO_2 into the air” as well as less NO_x and SO_x or the secondary pollutants that result (i.e., “less smog” or “less acid rain”). Students also described the negation of particulate pollution and the absence of mercury and lead in the emissions from natural gas.

- In part (c) student responses earned a point by correctly describing an economic advantage for using natural gas rather than coal in producing electricity. Students did this by providing genuine knowledge of the differences between and within the two processes. For instance, students recognized that natural gas can be “transported more cheaply within pipes” or that natural gas “burns cleaner and you won’t pay fines for polluting the air.” Students also had a good understanding of the higher efficiency of a natural gas powerplant as opposed to a coal powerplant and that better efficiency means less fuel needed and therefore lower fuel costs.

- In part (d) students were aware that carbon monoxide (CO) poisoning can be solved by not creating CO, not allowing CO into the home's living space, or warning the occupants if CO is present. Many student's responses involved installing carbon monoxide detectors or alarms. Students also earned this point by advising to heat the home by other means such as passive solar or active solar serving an electric heater or by maintaining the natural gas furnace and venting the combustion products to the building exterior.
- In the second, calculative part of this question, many students worked systematically and earned a significant number of points out of the six points available. Students demonstrated the ability to calculate a percent change in part (e), a decrease in an amount in part (f), and an increase in hospital admissions in part (g) from information supplied to them in the prompt. The use of calculators aided students in the math section as the values involved did not cancel in any fashion, and observable multiplication done by students without calculators appeared to be difficult and was often unsuccessful. Units, however, canceled nicely and therefore could be used to lead students to correct responses through dimensional analysis.

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 coal as being nonrenewable due to being created millions of years ago or only being able to be used once.	• "Coal is a non-renewable energy source because the resource is being used faster than it can replenish."
• Students described natural gas as being renewable or that combusting natural gas produced less emissions or that the emissions damaged the ozone layer.	• "less natural gas is required to produce the same energy than using coal, therefore also emitting less CO_2 gas"
• Students either described an advantage of gas over coal but then did not relate it to an economic gain or described an economic advantage not related to electricity production.	• "with gas pipe, the cost of transporting natural gas is way less than the transportation of coal"
• Students proposed a solution to carbon monoxide poisoning due to heating with natural gas as either vent room air to the outside or to filter the room air.	• "homes can have a carbon monoxide tester to let them know if carbon monoxide is present"
• Students did not calculate percent change effectively. Either division by the final value or only final divided by initial were not uncommon. Lack of units in the setup was common.	• (188 ug/m^3 – 85 ug/m^3) / 85 ug/m^3 x 100 = 121 %
• Students either did not include units in the setup or canceled the units ineffectively yielding a true answer but described by the wrong unit.	• (50,000 hectares x 2.3 kg/hectare) - (43,000 hectares x 2.3 kg/hectare) = 16,100 kg

• Students did not record all setup steps when manipulating given information to yield the correct answer, or students expressed the answer as the total admissions for next year when the increase in admissions was requested in the prompt.	• 23%/10% = 2.3 1% x 2.3 = 2.3% 7390 x .023 = 169.97 The anticipated increase in hospital admissions in the next year is 170 people.

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?

- Students should learn to read each question thoroughly and more than once. Then students should annotate the free-response question booklet with possible answers to each prompt and then elaborate upon the best answer with terms learned in their AP Environmental Science class.
- Students should evaluate AP Environmental Science exam calculation questions through multiple exposures to many suitable questions coupled with the application of strict standards during assessment. If a performed calculation is not fully correct, then that calculation is wrong, and the point will not be earned.
- Students should learn to answer the question or respond to the prompt as presented. Students often could have earned a point only to have that point withdrawn by stating a contradiction or establishing a connection to another aspect of environmental science where a connection does not truly exist. Not every anthropogenic gas causes ozone layer depletion, yet this connection is often observed in student responses. Also, students went beyond the stated calculation goal of the increased admissions in part (g) to submit the TOTAL number of hospital admissions for the following year.

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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