Chief Reader Report on Student Responses:

2018 AP® Computer Science Principles Free-Response Questions

- Number of Students Scored 72,187
- Number of Readers 485
- Score Distribution

Exam Score	N	%At
5	10,136	14.0
4	15,215	21.1
3	26,032	36.1
2	14,186	19.7
1	6,618	9.2

- Global Mean 3.11

The following comments on the 2017 free-response questions for AP® Computer Science Principles exam were written by the Chief Reader, Paul Tymann, Rochester Institute of Technology. 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.

Task: Create Performance Task	**Topic:** Applications of Ideas	
	Mean Score:	**Max. Points:**
Developing a Program with a Purpose	0.92	1
Criteria 2	0.31	1
Criteria 3	0.56	1
Criteria 4	0.90	1
Criteria 5	0.69	1
Criteria 6	0.36	1
Criteria 7	0.71	1
Criteria 8	0.54	1

What were the responses to this question expected to demonstrate?

Developing a program with a purpose

- Students were expected to demonstrate the ability to design and create a program for a particular purpose. The program could be used to solve a problem, or for the student's own personal creativity.
- Students were expected to describe the process that was used in the development of their program. Students were asked to describe or outline steps used in the incremental and iterative development process used to create their program, to identify at least two program development difficulties or opportunities, and describe how the two identified difficulties or opportunities were resolved or incorporated.

Applying Algorithms

- Students were expected to demonstrate an understanding of how to develop and implement algorithms in a program. In particular, students are expected to recognize and use algorithms as building blocks by integrating and combining them to create a new algorithm. Students were asked to highlight a code segment that implements an algorithm that they developed and that uses mathematical or logical concepts. Students were expected to explain how the algorithm functions and describe what the algorithm does in relation to the overall purpose of their program.

Applying Abstraction

- Students were expected to use abstraction in a program to manage complexity. Students were asked to highlight a code segment that illustrated the use of abstraction in their program. Students were asked to explain how the abstraction helped to manage the complexity of their program or how the program might function differently if this abstraction was not used.

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

Developing a program with a purpose

- Students were asked to create a video that demonstrates the running of at least one feature of their program. Students were able to create a video that clearly and accurately illustrated the purpose of the program.
- Students were asked to describe the process they used to develop their program, focusing on two distinct points in the process. While most students were able to identify two distinct points in the process, many did not describe an incremental and iterative development process. Most responses only focused on the two difficulties and/or opportunities, and did not discuss the development process that was used. Responses regularly described the process used to select a project or develop the project idea rather than focusing on the actual program development (coding) process.

Applying Algorithms

- Students were asked to select an algorithm that integrated mathematical and/or logical concepts and that integrated two or more algorithms. Students were also asked to accurately identify the purpose of the algorithm and describe how at least one of the two integrated algorithms works independently. While most students were able to identify an algorithm in their program that used math and/or logic, a significant number of students chose algorithms that were trivial. Many responses did not discuss the purpose of the algorithm in the program.

Applying Abstraction

- Students were asked to provide a code segment that represented an abstraction and explain how this abstraction served to manage complexity of the program. While many students were able to accurately select an abstraction, some students selected predefined abstractions (e.g. event handlers), and some struggled to explain clearly why the abstraction manages complexity within the context of their program. Some students associated complexity with making the program more challenging for the user (e.g. a game program).

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

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
Responses 1 and 2a: *Developing a Program with a Purpose* Row 1 • Submitting screenshots of program code or submitting very short videos that did not show clear execution of the program resulted in a low score. • Failing to clearly describe the purpose of the program either in the video or the written response.	Row 1 • High scoring submissions included a full0-length video (approximately one minute) that clearly illustrated the program running. • High scoring responses clearly described the purpose of the program. For example, “The purpose of the program is to have the user plan its placement and attacks to ultimately take over every cell and win the game.”

Response 2b: *Developing a Program with a Purpose* Row 2 • Writing exclusively about time spent brainstorming ideas prior to beginning design and implementation of the program. Additionally, including extensive descriptions of work done independently or collaboratively. • A significant number of responses did not focus on the development process (coding) of the entire program. Row 3 • Describing difficulties in determining what type of program to create is not part of the development process. • Identifying difficulties but not describing specifically how they were resolved received a low score. • Describing knowledge gaps in terms of programming skills as difficulties and identifying learning the skills as their resolution process. • Identifying a difficulty and an opportunity encountered during the development of the program, and clearly indicating what was done to address the situation.	Row 2 • High-scoring submissions described the overall development of the program, which included the design of the user interface, the algorithmic components needed for the program, and the debugging and testing process as the program was put together. Row 3 • High-scoring submissions included details about portions of program code that weren't functioning properly. The descriptions included how errors were identified and resolved independently or by working with a partner. • High-scoring submissions clearly described what was done to resolve difficulties and incorporate opportunities. For example, "I used a debugger to determine that my loop count was off by one. I corrected the corresponding code and the program worked as expected," as opposed to "I fixed a problem in my program."
Response 2c: *Applying Algorithms* Row 6 • Responses did not clearly identify the selected and integrated algorithms, nor did they clearly describe the role of all three algorithms in the written response. • Circled more code than they described in written responses, indicating they did not necessarily understand the notion of an algorithm and how it can use other algorithms to solve a problem. • Selected and described two algorithms and stated that these algorithms work together as their overall selected algorithm. • Selected algorithms that contain only one line of code (i.e., one computation) received a low score.	Row 6 • Responses clearly identified the selected algorithm and at least two algorithms. High-scoring submissions described the selected algorithm in addition to the two separate algorithms that were used by the selected algorithm. • Responses that selected and described a procedure that had non-trivial computation and called out two additional procedures that each had their own non-trivial computation and had math and/or logic received a high score. • Responses that received high scores clearly identified the selected algorithms and integrated algorithms, both in the code fragment using ovals, as well as in the written response.

Response 2d: *Applying Abstraction*	
Row 7 and 8 • Unclear responses did not clearly identify the abstraction nor did they clearly describe the selected abstraction in the written response. • Responses that selected an abstraction that was not student-defined (e.g. an event handler or a for loop) received lower scores. • Some responses associated the term "complexity" as a requirement to make the program more complex (e.g. in a game) rather than program code. • Some responses indicated that abstraction can manage the complexity for the user of the program by making it easier to use.	Row 7 and 8 • High-scoring submissions included student-defined abstraction, like a procedure or a data list. These submissions clearly explained how the abstraction managed complexity through code reuse, improved readability, encapsulation, reduction in code due to data abstractions like a list (e.g. a list allows use of a loop to examine all elements), and/or improved debugging. • High-scoring submissions included the abstraction, as well as code that used the abstraction to illustrate clearly how it manages complexity.

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

Developing a Program with a Purpose - Submission Requirement 1 and 2a:

- Give students several opportunities to complete a practice Create performance task of shorter duration to gain a better understanding of the learning objectives and required responses. Have students view high-quality examples of the Create performance task to become familiar with the requirements. Completing these would also give students multiple experiences using an iterative and incremental development process in action so they are comfortable using and describing it in their submissions.
- Ensure that students have access and opportunity to practice how to use computational video tools to capture their program features.
- Students need additional practice making sure that any text in the video is clearly visible and readable for scoring.

Developing a Program with a Purpose - Submission Requirement 2b:

- Students should be reminded that when working on the performance task, they should not be getting any help from others outside of the class, including but not limited to family members, and students cannot get help from their teacher(s).

Applying Algorithms and Abstractions - Submission Requirements 2c and 2d:

- Students need to develop their skills by gaining experience taking screen captures of snippets of code and incorporating that snippet into a document in order to address a question or prompt requirements. Additionally, they need instruction on how to add circles and/or rectangles to their screen captures or access to tools that can do this.
- Students can and should include multiple program code segments to demonstrate the full utility of their algorithm and abstraction. These program code segments may come from more than one area of the program code.
- Teachers can review high-quality examples with students to help them understand the computational principles of algorithms and abstraction more clearly. For algorithms, show how each algorithm is independent; show how this is easier to explain when the integrated (additional) algorithms have separate functionality. For abstraction, show students how the program becomes more complex to manage when the abstraction is removed.

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

- Teachers should provide students with the Assessment Overview and Performance Task Directions for Students which is linked to the exam page on AP Central. This document provides clear guidelines for completing the performance tasks, including what students may and may not do during the administration.
- The assessment section of the Course and Exam Description provides teachers with similar guidelines for what they may and may not do to assist their students during the administration of the performance task.
- Teachers should review both sets of guidelines with students to help them understand why teachers cannot offer assistance during the administration of the task.
- Have students use a journal to record their development process, including when they have had to revisit early parts of their program, as these are examples of the iterative nature of the development. This will help students recall the incremental and iterative process used when developing their programs. The journal is also a helpful tool for teachers to determine the authenticity of student work.
- Students need more practice with small, open-ended projects that require them to set program development goals at a daily or weekly level. This will help them develop their skills reflecting on progress or difficulties throughout the year for smaller projects. This would also provide students with opportunities to develop project- and time-management skills.
- Additional student samples are added each year after the AP Reading. Teachers should spend time reviewing these samples, along with the Scoring Guidelines and Notes and Commentary, to help students understand how their work will be evaluated.

Task: Explore Performance Task	**Topic:** Applications of Ideas	
	Mean Score:	**Max. Points:**
Using Development Processes And Tools	0.92	1
Criteria 2	0.91	1
Criteria 3	0.89	1
Criteria 4	0.65	1
Criteria 5	0.64	1
Criteria 6	0.63	1
Criteria 7	0.65	1
Finding And Evaluating Information	0.54	1

What were the responses to this question expected to demonstrate?

Finding and Evaluating Information

- Students were expected to demonstrate the ability to reference, through in-text citation, at least 3 different sources.
- Students were expected to investigate and analyze a computing innovation that has had or has the potential to have both beneficial and harmful effects on society, economy, or culture. The computing innovation should consume, produce, and/or transform data, and raise a data security/privacy/storage concern.

Using Development Processes and Tools

- Students were expected to create a computational artifact that represents a computing innovation's purpose, function, or effect. The artifact must be student-developed, must identify the computing innovation, and and must provide an illustration, representation, or explanation of the computing innovation's intended purpose, function, or effect.

Analyzing Impact of Computing

- Students were expected to determine beneficial and harmful effects of a computing innovation, and explain how one of the identified effects relates to society, economy, or culture.

Analyzing Data and Information

- Students were expected to analyze the data a computing innovation uses, manipulates, or produces as well as any storage, privacy, or security concerns that is connected to the computing innovation.

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

Using Development Processes and Tools

- With the use of video and video presentations, students were able to create computational artifacts that conveyed a computing innovation's purpose, function, or effect.

Analyzing Impact of Computing

- While most students were able to identify beneficial effects of a computing innovation, many struggled to fully describe the effect and provide specific evidence tying it to society, economy, or culture. Additionally, many students did not include a harmful effect of a computing innovation.
- Students had a difficult time understanding the difference between the "function," "purpose," or "feature" of an innovation and an "effect." For example, a function of a mobile phone is to make phone calls, or to receive text messages. An effect is a result of the intended use of the innovation. For example, a mobile phone makes it possible call for help if my car breaks down; keeping me safer inside my car, rather than having to walk on the highway, or receive help from strangers.

Analyzing Data and Information

- While most students were able to identify the data being used or stored by a computing innovation, many struggled to describe in detail how a computing innovation used or transformed this data.
- Students were also able to identify a data concern, but many did not connect this concern to a computing innovation.

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

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
Responses 1 and 2a: *Using Development Processes and Tools* Rows 1 and 2 • Some students presented innovations that were not computing innovation. A computing innovation is one that includes a computer or program code as an integral part of its function. Responses did not clearly identify and describe the computer or program code that is part of the innovation. • Confusion between technology innovations with computing innovations. • Images and videos taken from the internet to create a computational artifact did not provide any acknowledgement. This is considered plagiarism, and will result in a score of 0 on the entire performance task.	Rows 1 and 2 • High-scoring submissions included descriptions of physical computing innovations such as Google glasses, non-physical computing software, such as cell phone applications, and eCommerce, which relies on transactions conducted on the Internet. • All successful submissions included acknowledgement of the source or author of any and all information or evidence taken from the work of someone else. Acknowledgements were done by adding a citation to the computational artifact itself, by adding a credits page to a video, or by including these with the references included in submission requirement 2e.
Response 2c: *Analyzing Impact of Computing* Row 3 • Responses indicated that students are confused by the term "effect." An effect is something that happens as a result of the intended use of the innovation. For example: "One of the beneficial effect of iphone x is it's display. The iphone x has a Organic Light Emitting Diodes (OLED) display technology." This is a feature of the phone, not an effect of the phone	Row 3 "A beneficial effect is that blockchain will save money on financial services infrastructure – since it's distributed, it is safer by design – and this security will allow the financial sector to decommission expensive systems that are currently used to secure transactions."

• Confusion between a direct effect of a computing innovation and an outside influence that might serve to break the innovation. Some examples of harmful effects that wouldn't be considered direct effects of a computing innovation include the cost of a computing innovation (e.g., being too expensive), or the ability of a computing innovation to be hacked. The effect must be a result of the intended use of the innovation. Row 4 • While students will often provide two effects, responses did not clearly indicate whether the effects are harmful or beneficial. For example, "EMG prosthetic limbs provide limbs to those who were either born without limbs or lost them in an accident," does not identify this effect as beneficial or harmful. • Responses did not explain why the identified effects are harmful or beneficial. For example, "Through the use of Apple Pay, less people have access to the user's credit card number making it much more difficult to steal the user's credit card information," does not explain why this is a benefit. Row 5 • Responses did not effectively connect one of the effects to society, economy or culture. The responses should explain how the effect is connected to society, economy or culture.	Row 4 "Augmented reality has significant potential to change the way we interact in the future, by providing us with beneficial information such as time, messages, directions, and other relevant or timely information with ease." Row 5 "The fact that the Microsoft HoloLens can make the gaming experience so realistic can be a problem in the society as users of the Microsoft HoloLens can be addicted to it."
Response 2d: *Analyzing Data and Information* Row 6 • Responses showed confusion between the devices used to collect data and the data itself. One example, cameras on self-driving cars are not data, the images that the cameras collect on the other hand are data. Another example: "The Microsoft HoloLens inputs data by using different types of cameras, microphones, and a light sensor."	"The Ultra contains an altimeter that is used to determine your elevation throughout the day. Using the elevation data, the Ultra can determine how much elevation you lose or gain throughout a day."

• Responses neglected to demonstrate understanding of how a computing innovation uses and transforms data. For example, a submission might identify that a computing innovation stores video, but neglects to explain how this video is being used. Row 7 • Responses stated a data privacy concern, such as hacking, without an analysis that connects the concern to a computing innovation and a description of how the obtained data might be used to violate privacy rights.	"If some people don't take actions on their privacy, such as sharing their profiles to the rest of the world, then they may allow other people to find out personal information about them such as gender, where they live, how old they are, and other possible information."
Response 2e: • Responses neglected to show a clear connection between the in-text citation and the reference section. For example, using numbers in the in-text citation without including a corresponding number in the references.	

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

Using Development Processes and Tools

- Give students several opportunities to complete a practice Explore Performance task to gain a better understanding of the learning objectives and required responses, and have students view high-quality examples of the Explore Performance Task to become familiar with the requirements.
- Ensure that students have access and opportunity to practice how to use computational video tools to capture their program features and narration.
- Students need additional practice making sure that any text in the video is clearly visible and readable for scoring.
- Based on the responses, it is clear that students still do not have a comprehensive understanding of what qualifies as a computing innovation. Have students identify several potential computing innovations and illustrate ways they are or are not acceptable for the Explore Performance task.
- Most students listed features of the computing innovation instead of illustrating the innovations intended purpose or function. Helping students to understand the difference between the features of an innovation and the purpose of the innovation would result in higher scores.
- Remind students that the computational artifact must be student developed. Submitting an artifact that was simply copied from the internet is not allowed. It is permissible to make use of artifacts found on the internet, but their use must be cited.

Analyzing Impact of Computing

- Explain to students the importance of selecting an innovation that has easily identifiable effects, data, and data storage/privacy/security concerns.
- Student responses would often confuse function and effect. Class exercises that give the students multiple opportunities to identify the function and effects of several computing innovations would help students to internalize the concept.

- Provide students with multiple opportunities to identify beneficial or harmful effects of computing innovations, AND describe why the effects are harmful or beneficial. Providing examples of what cannot be considered as beneficial and harmful effect would result in higher scores.

Analyzing Data and Information

- Provide students with examples of computing innovations that make use of data that is easy to identify and that have clear data privacy/security/storage concerns. Have students identify the specific data that is used. For example, a self-driving car has a sensor that collects location data.
- Give students multiple opportunities to identify data storage, data privacy, and data security concerns of computing innovations.

Finding and Evaluating Information

- Students should be reminded that when working on the performance task, they should not be getting any help from others outside of the class, including but not limited to family members, and students cannot get help from their teacher(s). Interview individuals outside of class for background information is allowed, however, if information from the interview is included in the response, it must be cited.
- Students need to develop the ability to properly cite and provide references. This could be done by providing them with several articles during the course that include citations and references. A specific style of citation (e.g. MLA) is not required in a response, but the response must provide and cite at least three references to receive a high score.

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

Suggested Resources Include:

- Teachers should provide students with the Assessment Overview and Performance Task Directions for Students which is linked to the exam page on AP Central. This document provides clear guidelines for completing the performance tasks, including what students may and may not do during the administration.
- The assessment section of the Course and Exam Description provides teachers will similar guidelines for what they may and may not do to assist their students during the administration of the performance task.
- Teachers should review both sets of guidelines with students to help them understand why teachers cannot offer assistance during the administration of the task.
- Have students use a journal to record notes and quotes from their research. This will help students to properly include in-text citations to back up their claims. The journal is also a helpful tool for teachers to determine the authenticity of student work.
- Additional student samples are added each year after the AP Reading. Teachers should spend time reviewing these samples along with the Scoring Guidelines and Notes and Commentary to help students understand how their work will be evaluated.