Chief Reader Report on Student Responses:
2020 AP® Computer Science Principles Performance Tasks

- Number of Students Scored: 116,751
- Number of Readers: 868
- Score Distribution:

Exam Score	N	%At
5	12,775	10.9
4	27,551	23.6
3	43,279	37.1
2	23,131	19.8
1	10,015	8.6

- Global Mean: 3.09

The following comments on the 2020 free-response questions for AP® Computer Science Principles were written by the Chief Reader, Paul Tymann, Rochester Institute of Technology. They give an overview of each performance task 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:** Application from Ideas
	Max. Points:	**Mean Score:**
Row 1	1	0.90
Row 2	1	0.43
Row 3	1	0.60
Row 4	1	0.88
Row 5	1	0.67
Row 6	1	0.41
Row 7	1	0.72
Row 8	1	0.57

What were the responses to this question expected to demonstrate?

Programming is a collaborative and creative process that brings ideas to life through the development of software. Programs can help solve problems, enable innovations, or express personal interests. In this performance task, students developed a program of their choice. The students' development process includes iteratively designing, implementing, and testing their program. Students were strongly encouraged to work with another student in their class.

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?

Developing a program with a purpose

- Students were asked to develop a working program and use a video to demonstrate the running of at least one feature of their program. In general, students were able to write a working program and create a video that clearly and accurately illustrated the purpose of the program.
- Students were asked to describe the incremental and iterative development process they used to develop their program, focusing on two distinct points in the process. In general, most students were able to identify two distinct points in the process as difficulties or opportunities, however many students were *not* able to describe the incremental process or the iterative process. Some students would either describe the development process or describe two distinct points as difficulties or opportunities. Compared to previous years, students seemed to be getting better at the incremental development, but there seemed to be a lot of confusion about iteration. Students talked about iterative programming elements such as loops rather than an iterative design process (checking the code, finding bugs, correcting, repeating the process with feedback from others, repeating the process for improvements).

Applying Algorithms

- Students were asked to incorporate complex algorithms into their program that integrated mathematical and/or logical concepts and that integrated two or more algorithms, to accurately identify the purpose of the algorithm, and describe how at least one of the two integrated algorithms works independently. While students were able to identify an algorithm in their program that used mathematics and/or logic, a significant number of students chose algorithms that were trivial. Many students would describe how the algorithm functioned but would not describe the role of the algorithm in the overall program. Few responses explicitly identified the two integrated algorithms.

Students who did identify the integrated algorithms, often failed to explain how one of them functioned independently.

- Students seem to struggle with the algorithms by selecting completely unrelated algorithms and trying to claim they are sub-algorithms of each other. While these two parts of the code may help/work together to achieve a certain purpose, students are missing that the start of one of their algorithms will not sequence, select, or iterate into the other algorithm.
- Some students identify code that defines a function where the function is not called and talk about the function as a sub-algorithm in the written response. Without identifying the code that calls this function, it is hard to explain how this function acts as a sub-algorithm to support another function.

Applying Abstraction

- Students were asked to highlight a code segment that illustrates the use of abstraction in their program, 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. Students continue to confuse abstractions with algorithms. Often the abstraction selected was an important algorithm. When discussing the abstraction, students would discuss the importance of their algorithm and how it managed some complex aspect of the game. They would do this instead of talking about abstracting out the functionality of the code to put into a method that could be reused or helpful in overall program design.

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 • Videos that do not demonstrate that a working program has been created. • Programs based on curriculum provider activities with trivial modifications resulted in a low score. Depending on the scope of the modifications, these programs may be flagged as a security violation.	Row 1 • High scoring submissions include a full-length video (approximately one minute) that clearly illustrates the program running. • High scoring responses clearly described the purpose of the program. For example, *"to help users memorize terms and their definitions more effectively."*

Response 2b: *Developing a Program with a Purpose*	
Row 2 • Writing exclusively about time spent brainstorming ideas prior to beginning the design and implementation of the program. • A significant number of responses did not address the development process (coding) of the entire program. They begin describing the process but move to the description of the difficulties and opportunities and never fully address the complete development process. • Confusing "iterative development" with iteration. Students would conflate "iterative development" with keeping track of the "number of lives" in a game.	Row 2 • High scoring submissions describe the overall development of the program, which can include the design of the user interface, the algorithmic components needed for the program, and the debugging and testing process as the program is developed. For example, *"...setting up the background and arranging the cards before developing the Card class ... determined the coordinates ... tested the program multiple times ... confirm the accuracy of the program by running it to check if it worked ... getting them [cards] to flip.*"
Row 3 • Describing difficulties in determining what type of program to create is not part of the design and implementation of the program. • Identifying difficulties or opportunities but not describing specifically how they were resolved or incorporated. For example "I looked in our examples from class and I was able to fix it." • Describing knowledge gaps in terms of programming skills as difficulties and identified learning the skills as their resolution process.	Row 3 • High scoring submissions include details about portions of program code that were not functioning properly. The descriptions included how errors were identified and how these difficulties were resolved. • High scoring submissions clearly described the difficulty was resolved or how the opportunity was incorporated. 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 4 • Writing a program that consists only of a few buttons and switches screens when a button is clicked. These responses leave little or no evidence of algorithms.	Row 4 • High scoring submissions clearly identified a non-trivial algorithm with sequence, iteration, and/or selection.
Row 5 • Identifying an algorithm with mathematics or logic, but not explicitly describing what the algorithm does in relation to the overall purpose of the program. • Describing what an algorithm does in relationship to the overall program or explaining how an algorithm functions, but not both. • Immediately focusing on what the included algorithms do, but not fully addressing the overall purpose and function of the whole selected algorithm.	Row 5 • High scoring submissions explicitly describe what the algorithm does in relation to the overall program and describe how the algorithm functions. For example: "*My main algorithm is the 'calculatetotalweightedGPA' function. This algorithm allows users to be notified of their final weighted GPA. The algorithm takes the results from its three sub-algorithms, which calculate the point value earned from honors classes, AP classes, and regular classes. The algorithm adds the values earned from the three sub-algorithms, and divides them by the total number of classes, seven … These three sub-algorithms are integrated into the main algorithm, ensuring that the different weights of different class types are taken into account when calculating the final weighted GPA.*"
Row 6 • Identifying the selected algorithm without clearly identifying either one of the two integrated algorithms. • Identifying more program code than described in the written response. • Selecting and describing two non-integrated algorithms • Selecting algorithms that contain only one line of code (i.e., one computation). • Confusing the independent creation of algorithms with how algorithms function independently. • Identifying two algorithms but not describing how one of them functions; often only addressing the general purpose of the sub-algorithms	Row 6 • High scoring submissions include a non-trivial algorithm and clearly identify two non-trivial integrated algorithms, AND explain how at least one of the integrated algorithms functions on its own. • Some high scoring answers include a non-trivial function that explicitly calls two separate functions, and all three functions are identified, with one of the called algorithms being explained clearly.

Response 2d: *Applying Abstraction*	
Row 7 and 8 • Identifying an abstraction that is not student-defined (e.g., an event handler or a for loop). • Describing how the abstraction functions as an algorithm, as opposed to how the abstraction manages complexity in the program. • Describing how the abstraction manages complexity from the end-user perspective. For example: *"This abstraction UpdateTScore1 and UpdateTScore2 manages the complexity of the program as it allows the players to not remember what score they have in total and they don't need to have a hard time remembering how much score did they win in each round."*	Row 7 and 8 • High scoring submissions include a student-defined abstraction like a procedure or a data list. These submissions clearly explain how the abstraction manages 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. For example: *"By using the same function in two different locations and changing the parameter values, less lines of code are used and a reusability is increased in the program."* • High scoring submissions include both the abstraction as well as code that uses the abstraction to clearly illustrate how it manages complexity. • Although not common, students who have a solid understanding of how abstraction manages complexity but selected an abstraction that is not student-defined can still identify how the abstraction managed complexity. An example where the student selected a built-in block that created and customized multiple clones of a sprite: *"This abstraction is used to create all of the grade options A-F in one quick step. This simplifies the code and manages complexity by creating all of the buttons off of one starter button that repeats through the different costumes..."*

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?

Developing a Program with a Purpose - Submission Requirements 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 skills required for the program. Completing these would also give the students multiple experiences using an iterative and incremental development process in action so they are comfortable using and describing it in their submissions.
- Have students view high-quality examples of the Create Performance task to become familiar with the performance task requirements.
- Ensure that students have access and opportunity to practice using computational video tools to capture their program features. Integrate the use of computational tools such as screen capture and creating short videos into multiple assignments.
- Students need additional practice making sure that any text in the video is clearly visible and readable for scoring. If using a voice-over narration, encourage recording using a loud, clear voice in a noise-free environment.
- Make it clear to students that while it is okay to base their program on a program used in class, they must make significant changes to the program by adding additional functionality. For example, changing a one-player game to be a two-player game. However, changing the background, or sprites used in a program is not a significant change.

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

- While students may work collaboratively on their projects, they may not get help from others outside of the class, including but not limited to family members. Students cannot get help from their teacher(s). Students need more experience creating programs using an incremental and iterative development process. Encourage students to keep a log of the work they do on their projects. When the project is done reviewing the log will help them describe the development process that was used.
- Practice describing the iterative development process as well as the incremental process. Practice should include writing the descriptions. Strategies like peer review can help manage the time of incorporating multiple practices and providing feedback.

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

- Students need explicit instruction and experience taking screen captures of code segments and incorporating them into their written responses. Additionally, they need instruction on how to add circles and/or rectangles to their program code.
- Students can and should include multiple program code segments to demonstrate the full utility of their algorithm and abstraction, such as procedures along with the call to the procedure. Teachers can provide multiple opportunities for students to understand both visually and conceptually the relationship between multiple code segments. 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.
- Teachers must not provide students with task templates that provide fill-in-the-blank spaces for task requirements. These are a violation of the performance task guidelines and can result in student submissions being flagged for plagiarism.

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 official Student Handouts as well as the scoring guidelines, rather than relying on only the scoring guidelines or a modified version of the task directions. This document provides clear guidelines for completing the performance tasks, including what student may and may not do during the administration.
- The Exam section of the Course and Exam Description provides teachers with guidelines for administering the performance tasks to students.
- The Exam page on AP Central provides teachers and students with example student responses to the performance tasks along with scoring commentaries for how these responses would be scored.
- AP Classroom (myap.collegeboard.org) provides teachers with a set of formative performance task prompts that can be paired with existing projects to provide students with scaffolded practice for the written response prompts.

Task: Explore Performance Task | **Topic:** Impact of Computing Innovations

	Max. Points:	Mean score:
Row 1	1	0.93
Row 2	1	0.92
Row 3	1	0.89
Row 4	1	0.68
Row 5	1	0.65
Row 6	1	0.68
Row 7	1	0.73
Row 8	1	0.65

What were the responses to this question expected to demonstrate?

Computing innovations impact our lives in ways that require considerable study and reflection for us to fully understand them. In this performance task, students explored a computing innovation of their choice. The close examination of this computing innovation deepens the students' understanding of computer science principles.

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?

Using Development Processes and Tools

- Students were able to create computational artifacts that conveyed a computing innovation's purpose, function, or effect.

Analyzing Impact of Computing

- 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 social media application is to help users communicate and share information. An effect is a result of the intended use of the innovation. For example, social media enable subscribers to maintain relationships with family and friends who live geographically far apart by sharing live events in videos and images.
- Many students were ineffective when identifying harmful effects from the use a computing innovation instead including negative details related to the manufacturing process or functionality of the innovation.

Analyzing Data and Information

- Students had a difficult time separating the data from the sensors or type of information the innovation uses. For example, "Augmented reality applications use several important hardware components: a processor, output display, sensors, and input devices." The student does not explicitly identify the data used to input, transform, or output augmented reality visualizations in their response.
- Students who were able to identify the data being used, sometimes did not clearly explain how the innovation consumes, produces, or transforms data.
- Students were able to identify a data security/privacy/storage concerns related to the chosen computing innovation.

Finding and Evaluating Information

- Most students included at least three references in their response, but often did not cite three different references in their response.

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
Responses 1 and 2a: *Using Development Processes and Tools*	
Rows 1 and 2 • Investigating an innovation that is not computing innovation. A computing innovation is an innovation that includes a computer or program code as an integral part of its function. According to this definition a smartphone would be a computing innovation, whereas 5G would not be. The response must clearly identify and describe the computer or program code that is part of the innovation. • Confusing technology innovations, such as a Bluetooth, with computing innovations, such as the applications used to output audio to Bluetooth-enabled devices.	Rows 1 and 2 • High scoring submissions included descriptions of physical computing innovations such as virtual reality, augmented reality, Instagram, Google Translate, GPS, and facial recognition software. • All submissions must include acknowledgement of the source or author of all information or evidence taken from the work of someone else. Acknowledgements can be 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 • Confusing an "effect" with a purpose, function, or feature. An effect is something that happens as a result of the intended use of the innovation. For example: "*One beneficial effect of 3D printing is that it allows for people to print models in plastic or metal particularly for parts that are not in production anymore.*" This is the purpose of 3D printing, not an effect of 3D printing.	Row 3 • High scoring submissions clearly identify a result (effect) of the intended use of the innovation. For example: "*A beneficial effect of 3D printing is that it allows for people to be less wasteful by create or produce replacement parts to specification from a saved model or scanned original, allowing a product to be fixed rather than thrown away.*"

Row 4 • Identifying two effects, without clearly indicating whether the effects are harmful, or beneficial: "*Instagram makes sharing pictures with my family quick and easy but can also cause hurt feelings*."	Row 4 • High scoring submissions clearly identify both a harmful and beneficial effect of the innovation receive this point. For example, beneficial effect: *"A positive effect of using Instagram is that grandparents stay connected with family by seeing pictures and videos whenever they log on"* And a harmful effect: "*One harmful effect of social robots is that they can help people with jobs around the house, but they are taking jobs from homecare providers such as nurses."*
Row 5 • Connecting at least one of the identified effects to society, economy or culture.	Row 5 • High scoring responses clearly tied an effect of the innovation to society, economy, or culture: *"A beneficial effect is facial recognition allows for greater security for personal devices. This security, due identifying data points on the device owner's face, will only open or activate for the true owner making it more secure than a password."*
Response 2d: *Analyzing Data and Information*	
Row 6 • Not clearly identiying the data used by the innovation: *"Smartwatches use data from the phone and the user taking in information to create outputs."* • Neglecting to demonstrate understanding of how a computing innovation uses and transforms data. For example, a submission might identify that a computing innovation takes in GPS location data but neglects to explain how these numeric coordinates are being used by the application.	Row 6 • High scoring responses clearly identify the data used by the innovation: *"Google Duplex uses user input data such as name, phone number, date and time then processes calls using this data by transferring the information to the receivers through automated audio calls using a realistic human voice."*

Row 7 • Stating a data storage, privacy, or security concern without stating how the concern is connected to the computing innovation: *"The way Skype filters it through a third party, (although it is a bot), causes worry over the security of the conversations."*	Row 7 • High scoring responses clearly identified the concern, and described how the concern was tied to the innovation: *"A security concern about the data collected is that it could be either hacked into or sold to other establishments without the person's consent. This is something that happened at a similar social media platform called Facebook"* • Or "*One concern of facial recognition technology is invasion of privacy. Since there are no specific rules as to where this kind of technology can be used, it is unknown where and how the public image data is stored and accessed."*
Response 2e: *Finding and Evaluating Information*	
Row 8 • Neglecting to provide in-text citations.	

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 skills required to answer the prompts.
- Have students view high-quality examples of the Explore Performance Task to become familiar with the performance task requirements.
- Ensure that students have access and opportunity to practice using the tools to be used to create computational artifacts.
- 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 a computing innovation that has easily identifiable effects, data, and data storage/privacy/security concerns.
- Class exercises that give the students multiple opportunities to identify the function and effects of several computing innovations would help students to internalize the difference.
- Provide students with multiple opportunities to identify beneficial or harmful effects of computing innovations.

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). Interviewing individuals outside of class for background information is allowed, however, if information from the interview is included in the response, it must be cited.
- Provide clear instruction and practice constructing proper citations and 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?

- Teachers should provide students with the official Student Handouts as well as the Scoring Guidelines, rather than relying on only the scoring guidelines or a modified version of the task directions. This document provides clear guidelines for completing the performance tasks, including what student may and may not do during the administration.
- The Exam section of the Course and Exam Description provides teachers with guidelines for administering the performance tasks to students.
- The Exam page on AP Central provides teachers and students with example student responses to the performance tasks along with scoring commentaries for how these responses would be scored.
- AP Classroom (myap.collegeboard.org) provides teachers with a set of formative topic questions that include a shorter stimulus with 1–2 questions that can be used to help students prepare for the multiple-choice questions that include a reading passage about a computing innovation.
- The Explore Curricular Requirements teacher resource found in AP Classroom or in the Course Audit has been designed to meet the 2020 Curricular Requirement for exploring computing innovations and will help students prepare for the multiple-choice questions that include a reading passage about a computing innovation.