Computer Science Principles

Free Response Questions Piloted in 2011-12

Computer Science: Principles is a pilot course under development. It is not an official Advanced Placement course currently being offered by the College Board.

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The following Computer Science (CS) Principles free response questions were developed by the College Board and the NSF-funded CS Principles Project for piloting purposes. They were piloted across ten high schools and eight colleges during the 2011-2012 academic school year. Instructors at these eighteen institutions participated in a year-long pilot project; each developed and taught a course that was based on the CS Principles framework, but the courses were different in how they approached this framework and in the pedagogical approaches used. The free response questions included here were designed to enable students to demonstrate mastery of learning objectives in the CS Principles Curriculum Framework and to assess how open-ended questions work in a CS Principles course. Student responses to these questions were part of the pilot assessment; these responses have provided statistical and evaluation data to inform a proof of concept for the development of a CS Principles AP Exam. Such an exam would likely contain objectively scored questions in addition to open-ended questions. The piloted free response questions included here do not necessarily reflect the types of questions that would be contained in an official AP exam.

Each question below is followed by a brief commentary on the intent of the question, as well as a list of the learning objectives and evidence statements elicited by the question. A future report will provide details into the student responses.

Free Response Question: Impact of the Internet

A widely expressed viewpoint is that the Internet dramatically changes people's access to information and thereby transforms society with associated benefits and risks, positive and negative impacts.

Choose two of the following four questions and write a brief response (a paragraph or a few sentences). High scores will be earned only by responses that explore both benefits and risks, demonstrate knowledge of the Internet, provide a credible argument rather than simply listing facts, and that use appropriate computing terminology.

For each question you respond to, you may use the example of computing technology provided or you may use a different, relevant example on which to base your response.

1. Browser cookies are an example of a computing technology that has privacy implications. Identify and explain one associated privacy benefit and one risk to individuals or society that stem from the use of browser cookies or another use of the Internet that has privacy implications.

2. Firewalls are an example of a computing technology that has security implications. Identify and explain one potential benefit and one associated risk to individual or societal security that come as a result of the use of firewalls or another aspect of the Internet that has security implications.

3. Broadband Internet access is an example of a computing technology that has economic implications. Identify and explain one associated benefit and one risk to individual or societal economics that develop from the use of broadband Internet access or another aspect of the Internet that has economic implications.

4. YouTube® is an example of a computing technology that has cultural implications. Identify and explain one associated benefit and one associated risk to individual or societal culture that derive from the use of YouTube or another use of the Internet that has cultural implications.

Commentary

Students in a CS Principles course will be expected to analyze, reflect on, and write about the content of the course. This problem provides an example of the kinds of analyses and reflections that teachers and students of CS Principles should be engaged with. Written responses should be complete and accurate and should provide reasonable detail. In terms of content, the intent of this problem is to elicit evidence that students can analyze the beneficial and harmful effects of computing and the Internet, can describe examples related to privacy and cybersecurity, can evaluate impacts of the Internet and the web on society, and can discuss the social, economic, and cultural contexts of computing.

Learning Objectives and Evidence Statements elicited with this question:

Learning Objective 30: The student can connect the concern of cybersecurity with the Internet and systems built on it. (Sub-questions 1, 2)
Evidence for Learning Objective 30: Student work is characterized by:
30b. Description of software, hardware, and human components involved in implementing cybersecurity.

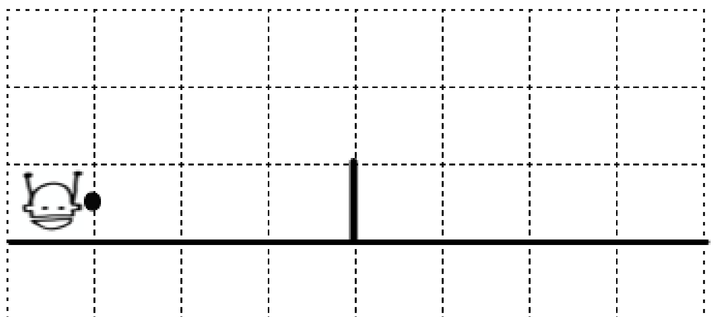
Learning Objective 31: The student can analyze how computing affects communication, interaction, and cognition. (Sub-questions 3, 4)
Evidence for Learning Objective 31: Student work is characterized by:
31b. Evaluation of impacts that the Internet and the web have had on society.

Learning Objective 34: The student can analyze the beneficial and harmful effects of computing. (Sub-questions 1, 2)
Evidence for Learning Objective 34: Student work is characterized by:
34b. Evaluation of privacy and security concerns that arise in the development and use of computational systems and artifacts.

Learning Objective 35: The student can connect computing within economic, social, and cultural contexts. (Sub-questions 3, 4)
Evidence for Learning Objective 35: Student work is characterized by:
35a. Identification of how computing innovations both influence and are influenced by the economic, social, and cultural contexts in which they are designed and used.
35b. Explanation of connections between the global distribution of computing resources and issues of equity, access, and power.

Free Response Question: Robot

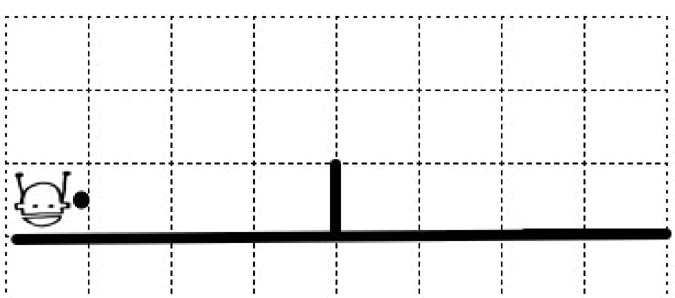
Consider a robot-programming environment in which one or more robots move in a grid world in which walls may be located. There is one robot named Fred in the diagram below. In the world below, there is a horizontal wall directly below Fred, and a vertical wall one unit high three units to the right of Fred. Robots can move one square at a time, can turn either left ninety degrees, and can turn right ninety degrees. The small black dot indicates the direction a robot faces (up, right, down, left). Currently Fred is facing right. Grid world squares extend infinitely in all directions but we only show some of the squares in each diagram.



The robots are programmed in Sparkle, which has been extended with three additional instructions or functions that are specific to this robot grid environment:

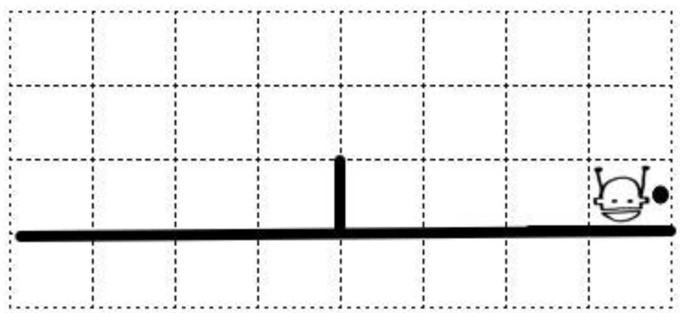
- **Move(robotName)**: The robot named robotName will move one square in the direction it is facing to an adjacent grid location. If a robot tries to move into a wall nothing happens.
- **TurnLeft(robotName)**: The robot named robotName will turn ninety degrees counterclockwise (left). For example, if the robot is initially facing Up, it will face Left after executing TurnLeft.
- **TurnRight(robotName)**: The robot named robotName will turn ninety degrees clockwise (right). For example, if the robot is initially facing Up, it will face Right after executing TurnRight.

In the following program, the robot named Fred moves across the grid, avoiding the wall in the middle. When the program stops Fred is three squares to the right of the wall as shown in the animation below.

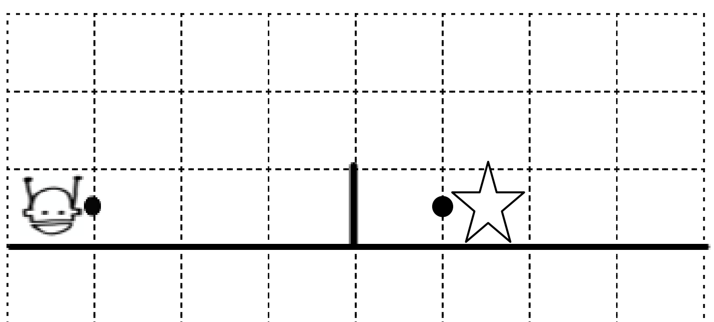


```
LOOP 3 TIMES {
    Move(Fred)
}
TurnLeft(Fred)
Move(Fred)
```

```
TurnRight(Fred)
Move(Fred)
TurnRight(Fred)
Move(Fred)
TurnLeft(Fred)
LOOP 3 TIMES {
    Move(Fred)
}
```



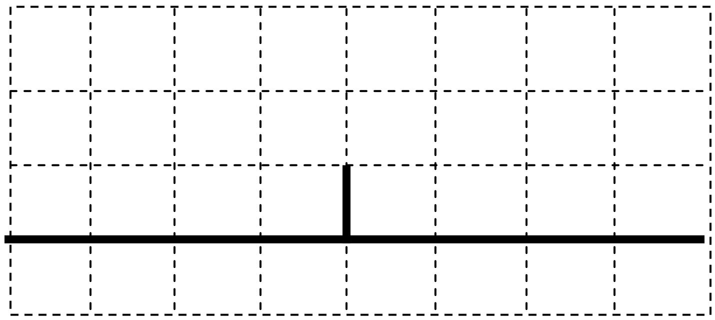
Part A: Consider the world below where there are now two robots, Fred and Star, and the following program that moves both of them. The Fred robot is shown as a head with two antennae, initially facing Right. The Star robot is shown as a star-shape, initially facing Left.



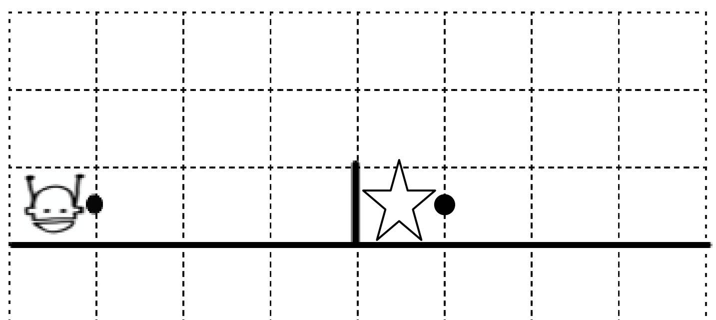
```
TurnLeft(Fred)
Move(Fred)
TurnRight(Fred)
LOOP 3 TIMES {
    Move(Fred)
}

LOOP 2 TIMES {
    TurnRight(Star)
}
LOOP 2 TIMES {
    Move(Star)
}
```

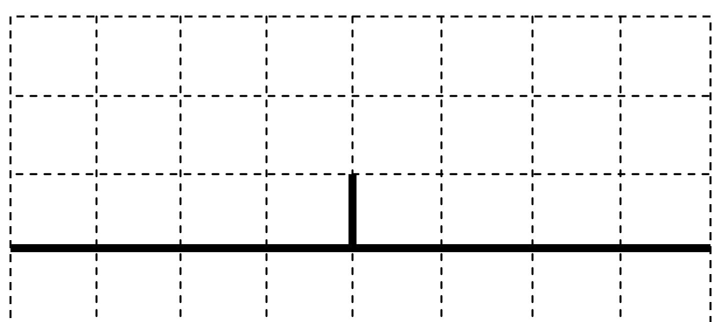
In the diagram below, draw the positions and the orientations of both Fred and Star after the code above is finished running. Be sure to make it clear which direction each robot is facing.



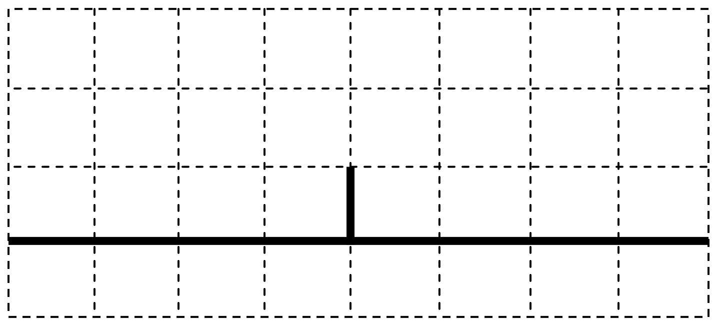
Part B: Now consider the following starting positions and orientations for Fred and Star. Both robots are facing Right, Star is four squares to the right of Fred and there is a wall directly to the left of Star.



Write a program that moves <u>either</u> Fred <u>or</u> Star from its current location so that the two robots are in adjacent squares and facing towards each other (black dot to black dot). As it moves, the robot must not pass through a solid black line. Before you write the program, indicate in the diagram below the squares that both Fred and Star would occupy and the direction they are facing after your program has finished running. You may move either Fred or Star. You may also turn both robots. Be sure the robots are next to and facing each other and the diagram you create is consistent with the code you present.



Part C: For this question you will be asked to reason about problem set in a grid world similar to what you saw in Part B. However, in this problem you do not know the initial locations of Fred and Star. As such, you should imagine that Fred and Star might be located anywhere, facing any direction on the grid below.



Although the initial locations of Fred and Star are unknown, you are asked to write a single program that moves Fred and Star from their starting locations into adjacent spaces facing each other as you did in Part B where you knew their initial locations and orientations. This cannot be done with the existing instructions/functions and Sparkle language provided. What additional instructions or functions or other modifications would you make to Sparkle to create one program to solve this problem? Explain briefly how you would use these new features to write a program that when executed would leave Star and Fred face to face in neighboring squares regardless of their starting locations and orientations. You do not need to actually write the program rather, describe precisely how you could use your proposed new modifications.

Commentary

Students in a CS Principles course are expected to write programs. The choice of languages is left to the individual instructors. This problem provides an example of a programming task that students should be able to complete, regardless of which languages they gained experience with in their coursework. In terms of content, the intent of this problem is to elicit evidence that students can develop a program, can analyze a program for correctness, and can employ abstraction in managing complexity.

Learning Objectives and Evidence Statements elicited with this question:

Learning Objective 18: The student can express an algorithm in a language. (Part C)
Evidence for Learning Objective 18: Student work is characterized by:
18a. Use of natural language, pseudo-code, or a visual or textual programming language to express an algorithm.

Learning Objective 22: The student can use abstraction to manage complexity in programs. (Parts B, C)
Evidence for Learning Objective 22: Student work is characterized by:

22a. Use of functions as re-usable programming abstractions. (Part C)
22d. Use of Application Programming Interfaces (APIs) and libraries to simplify complex programming tasks. (Part B)

Learning Objective 23: The student can evaluate a program for correctness. (Parts A, C)
Evidence for Learning Objective 23: Student work is characterized by:
23c. Justification of program correctness. (Part C)
23d. Explanation of how a program functions. (Parts A, C)

Learning Objective 24: The student can develop a correct program. (Part B)
Evidence for Learning Objective 24: Student work is characterized by:
24a. Use of an iterative process to develop a correct program.

Free Response Question: Data

In June of 2011 a conference titled "Information: Making Sense of the Deluge" used the quote below to express the purpose of the conference:

> *The world now contains unimaginably vast amounts of digital information, which is growing exponentially. The era of big data presents incredible opportunities --- smarter cities, stronger companies, faster medicine --- but just as many challenges. Storage is scarce, systems overloaded and governments and businesses know too much. Managed well, data can be used to unlock new sources of economic value, provide fresh insights into science and hold governments to account. Managed poorly, it can cause great harm.*

Using this quote as a starting point provide two examples of what are referred to as "incredible opportunities" that can arise from big data, and two examples of how big data can "cause great harm", as mentioned at the end of the quote.

Note: Take a few minutes to plan and outline your response. Only essays that use substantive examples from computing and computer science in explaining the quote will earn high scores.

Commentary

Students in a CS Principles course are expected to analyze, reflect on, and write about the content of the course. This problem provides an example of the kinds of analyses and reflections that teachers and students of CS Principles should be engaged with. Written responses should be complete and accurate and should provide reasonable detail. In terms of content, the intent of this problem is to elicit evidence that students can analyze the beneficial and harmful effects of computing, and can connect computing with innovations in other fields. In particular, the analyses and reflections in this question must relate to big data, not simply to changes engendered by computing and the Internet, for example.

Learning Objectives and Evidence Statements elicited with this question:

Learning Objective 33: The student can connect computing with innovations in other fields.
Evidence for Learning Objective 33: Student work is characterized by:
33a. Identification of the impacts of computing on innovation in other fields.
33b. Description of how computational approaches and data analysis enable innovation.
33c. Explanation of how computing enables innovation by providing access to and sharing of information.

Learning Objective 34: The student can analyze the beneficial and harmful effects of computing.
Evidence for Learning Objective 34: Student work is characterized by:
34a. Evaluation of legal and ethical concerns raised by computing-enabled innovations.
34b. Evaluation of privacy and security concerns that arise in the development and use of computational systems and artifacts.
34c. Evaluation of how technology enables collection, use, and exploitation of information about, by, and for individuals, groups, and institutions.

Free Response Question: Colors

The colors of the visible light spectrum and a rainbow are Red, Orange, Yellow, Green, Blue, Indigo, and Violet. Each color has a wavelength measured in nanometers (nm). For example, Orange has a wavelength between 590-620 nm and Blue has a wavelength between 450-475 nm. Here's the table for wavelengths for each visible color. [note to ETS: ideally include a small block of the appropriate color in the color column if color shows]

Color	Wavelength Range (nm)
Red	620-750
Orange	590-620
Yellow	570-590
Green	495-570
Blue	475-495
Indigo	450-475
Violet	380-450

A programmer has written the Sparkle code below to find the color associated with a sensor and to print that color name. *The Sparkle code below does this correctly*. The value of the variable **wave** is a wavelength value from the sensor. After sensing this value the code then prints the name of the color associated with that sensed value. For example, if the sensed wavelength is 500, the code prints "color for 500 is green" and if the sensed wavelength is 600 the code prints "color for 600 is orange". The code is shown with line numbers to make it easy to refer to the lines, the line numbers are not part of the Sparkle code.

```
1   colors := ["red", "orange", "yellow", "green", "blue", "indigo", "violet"]
2   low_wave :=  [620, 590, 570, 495, 475, 450, 380]
3   high_wave := [750, 620, 590, 570, 495, 475, 450]
4   index := 0
5   wave := GET_VALUE_FROM_SENSOR
6   id := "none"
7   LOOP-WHILE index < len(colors) {
8       if (low_wave[index] <= wave) AND (wave < high_wave[index]) {
9           id := colors[index]
10      }
11      index := index + 1
12  }
13  print "color for ",wave, "is", id
```

Part A: What is printed if the value read by the sensor and stored in **wave** is 400? Use words to explain your reasoning and make references to the code. You will not receive full credit if you simply write the correct answer for what it printed, you must also explain your reasoning as to why it is printed.

Part B: Another programmer has written a slightly different program to accomplish the same task.

```
1   colors := ["red", "orange", "yellow", "green", "blue", "indigo", "violet"]
2   wave_lengths :=  [750, 620, 590, 570, 495, 475, 450, 380]
3   index := 1
4   wave := GET_VALUE_FROM_SENSOR
5   id := "none"
6   LOOP-WHILE index < len(colors) {
7       if (wave_lengths[index] <= wave) AND (wave < wave_lengths[index-1]) {
8           id := colors[index]
9       }
10      index := index + 1
11  }
12  print “color for ”,wave, “is”, id
```

In a few sentences explain the differences between this program and the previous program. The differences occur on line 7 in the part B program (similar to line 8 of the part A program), in the initialization of the variable `index`, and line 2 of the part B program (which replaces lines 2 and 3 of the part A program). You should explain why the differences result in a correct program, not simply what the differences are.

Commentary

Students in a CS Principles course will gain experience with both algorithms and programs. The intent of this problem is to elicit evidence that students can evaluate programs for correctness and can evaluate algorithms analytically and empirically. Students must also be able to explain what programs do, not simply develop programs to solve a task.

Learning Objectives and Evidence Statements elicited with this question:

Learning Objective 20: The student can evaluate algorithms analytically and empirically. (Part A)
Evidence for Learning Objective 20: Student work is characterized by:
20c. Explanation of how an algorithm functions.

Learning Objective 23: The student can evaluate a program for correctness. (Parts A, B)
Evidence for Learning Objective 23: Student work is characterized by:
23c. Justification of program correctness. (Part B)
23d. Explanation of how a program functions. (Parts A, B)

Free Response Question: Internet

The Internet Protocol (IP) and the Domain Name System (DNS) are two important components of the Internet and the World Wide Web. Write a short response to each of the two questions below. You should take a few minutes to plan and outline your answer for each of the two questions.

(A) The Internet Protocol IPv4 was in widespread use from 1980-2012. There is a more recent protocol named IPv6 now used more frequently than in the past. With IPv6 128 bits specify an IP address whereas 32 bits specify an address using IPv4. IPv6 also includes support for Internet security that is not present in IPv4. Describe two examples for why the change in the number of bits per address is necessary and two examples for why security is necessary in the new, more recent IPv6 protocol compared to the IPv4 protocol.

(B) The Domain Name System or DNS translates human-readable addresses or hostnames like www.whitehouse.gov to IP addresses like 208.77.55.42 (IPv4) or 2001:db5:1f67::998:de4:7457:6d5 (IPv6). Describe one reason that DNS is useful for a person using a web browser to find information. Describe one characteristic of DNS that demonstrates your knowledge of how DNS is hierarchical.

Commentary

Students in a CS Principles course will be expected to analyze, reflect on, and write about the content of the course. This problem provides an example of the kinds of analyses and reflections that teachers and students of CS Principles should be engaged with. Written responses should be complete and accurate and should provide reasonable detail. In terms of content, the intent of this problem is to elicit evidence that students can explain characteristics of the Internet and the web as well as how each of these work. Students are also expected to provide analyses and reflections related to cybersecurity.

Learning Objectives and Evidence Statements elicited with this question:

Learning Objective 27: The student can explain the abstractions in the Internet and how the Internet functions. (Parts A, B)
Evidence for Learning Objective 27: Student work is characterized by:
27c. Description of evolving standards that the Internet is built on, including those for addresses and names.

Learning Objective 28: The student can explain characteristics of the Internet and the systems built on it. (Parts A, B)
Evidence for Learning Objective 28: Student work is characterized by:
28a. Identification of the use of hierarchy and redundancy in the Internet.
28b. Description of interfaces and protocols that enable widespread use of the Internet and systems built on it.

Learning Objective 29: The student can analyze how characteristics of the Internet and systems built on it influence their use. (Part B)
Evidence for Learning Objective 29: Student work is characterized by:
29a. Explanation of how hierarchy and redundancy help systems scale.
29b. Explanation of how interfaces and protocols enable widespread use.

Learning Objective 30: The student can connect the concern of cybersecurity with the Internet and systems built on it. (Part A)
Evidence for Learning Objective 30: Student work is characterized by:
30a. Identification of tradeoffs associated with the trust model of the Internet.
30b. Description of software, hardware, and human components involved in implementing cybersecurity.