“What Is a Computer?” What do Secondary School Students Think?

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ABSTRACT

Nationwide, efforts are focusing on taking computer science (CS) to scale in high school classrooms through the Exploring Computer Science (ECS) and AP CS Principles (CSP) courses. Recent inroads are also being made to take structured introductory curricula to middle school classrooms. Often, a starting point for teaching CS in middle and high school is a discussion around the seemingly simple question “What is a computer?” The question is aimed to help learners understand through debate and discussion what makes a computer a computer. This paper reports our analysis of (a) middle school students’ discussions around this question, and (b) high school students’ responses to an assessment question measuring this understanding. Our analyses of students’ comments and responses reveal that a discussion around “what is a computer?” may be problematic for students, as it tends to focus on the tool, the “computer.” We suggest that the discussion needs re-framing to focus instead on *computing and computation*.

Keywords

K-12 Computer Science; Curriculum; Middle School; High School.

1. INTRODUCTION

There is a growing consensus that all children should learn computational thinking (CT) [24] and be offered introductory experiences in computer science in their K-12 school years. Computing and CT are seen as foundational to all modern STEM work [11]. Until recently, computationally rich experiences for learners were provided mainly through disparate efforts in after-school settings [19], or in place of computer literacy in schools. These early efforts paved the way for more systemic endeavors to take computer science (CS) to scale in high school classrooms through the NSF-supported Exploring Computer Science (ECS) curriculum and AP CS Principles (CSP) high school courses. Both ECS and CSP emphasize core disciplinary ideas of CS, the creative and collaborative aspects of computing, and enactment of authentic CT practices in the process of problem solving and design. Moreover, ECS is designed to level the playing field for diverse students with enthusiasm for computing, but little to no background; its curricular content and professional development directly address issues of interest and equity in computing for underserved populations. Although the needs of high school

students across the US are being prioritized through pilot courses such as ECS and CSP, there is growing belief that experience with computing must start at an earlier age. Middle school is a key time for engagement with STEM fields [23]. Recent inroads in this space have been made through structured middle curricula e.g., Stanford University’s *Foundations for Advancing Computational Thinking* [8] and Harvey Mudd’s *MyCS* [21].

Prior research overwhelmingly shows lack of awareness of CS as a discipline among students [1,4,7,12,13,16, 25]. These studies suggest unequivocally that middle and high school students are completely unaware of what CS is about and often harbor negative stereotypes, and/or a “computer-centric” view of the discipline. This lack of awareness and misconceptions of CS likely impacts both students’ interests in CS and their course enrollment choices in high school and beyond [12]. One way to remedy the situation is to mold student conceptions of CS earlier in their education career [7]. As a result, several recent initiatives including curricular ones at the middle and high school level are aimed at building awareness about computing in addition to teaching computational problem solving.

An oft-used starting point for teaching CS in middle and high school curricula is a discussion around the question, “What is a computer?” It is aimed at helping learners discuss and discover the characteristics of a computer. It is considered a foundational question by some in CS, as it forms a backdrop to thinking about computing and recognizing that role that computers play in the world today. Despite its widespread use in recent curricula, much still isn’t known about secondary learners’ understanding of computers, how they respond to this question, or their pre-conceived notions about computers and digital devices. Knowing students’ prior knowledge and misconceptions around this question will be useful for secondary CS teachers.

This paper presents results from two independent studies that collected data pertinent to the question, “*What is a computer?*” The first study is situated in a middle school classroom that wrestled with this question before the start of an introductory CS and programming curriculum, and the second is in the context of Unit 1 of the ECS curriculum where students deliberate on this question in end-of-unit and end-of-course assessments.

2. Discourse around “What Is A Computer?”

ECS is designed around a definition of inquiry that focuses on a set of teaching and learning strategies through which students are expected and encouraged to help define the initial conditions of problems, utilize their prior knowledge, work collaboratively, make claims using their own words, and develop multiple representations of particular solutions [9,10,15]. ECS addresses the following topics over six units – Unit 1: Human-Computer Interaction; Unit 2: Problem Solving; Unit 3: Web Design; Unit 4: Programming; Unit 5: Computing and Data Analysis; and Unit 6:

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Robotics. Days 1 and 2 of Unit 1 are dedicated to the topic, “What is a computer?” where “the concepts of computer and computing are explored through examples of each” [9]. Middle school curricula fashioned on ECS, such as *MyCS*, similarly start the introductory CS course sequence with a discussion and debate around “What is a computer?”

Teachers are encouraged to draw out student questions and responses. So, for a question such as “What is a computer?” the curriculum is designed to help students arrive at a working definition rather than be provided with one formal definition. All responses to the question are considered valid; it is through debate and discourse that students’ thinking on the question is expected to evolve. These discussions are centered on questions such as “Is a cell phone a computer?,” “Are mp3 players computers?,” “What about appliances such as televisions, coffee makers, and washers?” The debate often involves the related question “why should an object be considered a computer?” which is meant to lead to a discussion around characteristics of computers. Coming to agreement on which characteristics are *key* to calling an object or device a computer helps formalize students’ responses to the “What is a computer?” question. Such an organic discussion is central to the idea of “computational discourse” [6], where learners build competencies in CT and CT language [5] by *knowledge building discussions* in concert with engaging in computationally rich activities.

3. METHOD

This section describes our analyses of middle and high school students’ responses to “What is a computer?” and related questions. We are drawing data from two independent research efforts—the first conducted with 7th and 8th graders in a public middle school classroom; and the second involving a pilot study of end-of-unit and end-of-course assessments created for ECS. We are working with two data sets in order to be able to highlight aspects of students’ prior knowledge around this topic at different grade levels, and to describe middle school students’ discussions and high school students’ understanding of this concept.

3.1 Middle School Student Conceptions

The question guiding this research was: *What are students’ commonly held notions of what a computer is and what sort of digital devices qualify as “computers”?*

3.1.1 Participants & Procedures

Students in a public middle school classroom in the San Francisco Bay Area were recruited to be part of an introductory CS intervention. The sample comprised 28 children from 7th and 8th grade (20 boys and 8 girls, mean age: ~12.3 years) enrolled in an elective class on “computer creations”. IRB consent and assent were sought from parents and students. Of these, 16 were in 7th grade, and 12 in 8th grade. Four of the students in the class were students with special needs or learning difficulties. The classroom teacher wished to try out the online discussion board feature of Schoology, the learning management system in use by the school, with her students. It was therefore decided that prior to the start of the introductory CS course, the students would engage in online discussions around “What is a computer?” and related questions on their own with *little to no intervention on the part of the teacher or researcher. The researcher would follow the discussion closely as an observer, and then have face-to-face discussions with the class using students’ ideas and talking points from the online discussion.* Using the online discussion board on

their own allowed the students’ discussions to flourish unfettered; it gave all students an equitable voice; and pre-empted any temptation a teacher would have had to express an opinion about students’ incoming ideas about what is or is not a computer.

The following questions were posted on the discussion board. DP2 and DP3 were inspired by students’ comments in response to DP1. The goal of DP1 was to extend students’ thinking beyond what we traditionally think or talk about as computers before getting them to think of defining features of a computer (DP2) and then applying their feature-based criteria more broadly to other digital devices and appliances to discuss and debate DP3.

Discussion Prompt #1 (DP1): *What is a “computer”?*

Are iPads and tablets computers? Cell phones? What counts or does not count as a computer? How would you decide?

Discussion Prompt #2 (DP2): *What are the criteria or necessary features to call something a computer?*

Discussion Prompt #3 (DP3): *What are some devices that are digital that you don’t think of as “computers”?*

Is a TV a computer? What about iPads? Or Smartphones? Or an ATM machine? What about Google Glass? What about the car GPS system? Or a microwave? Is an Xbox a computer? How about DVD players or iPods? What about a digital thermostat? Any other devices you can think of?

Before students embarked on this activity, the teacher worked with the students and drew up etiquette-related “norms” for class online discussions. Students were asked to respond to DP1 during class time and any time until the next class period. The following week, DP2 and DP3 were added based on the types of discussions that emerged in response to DP1. Following online discussions in response to these prompts, the researcher had an in-class discussion around the ideas the children had discussed online. The focus of this experience report however is to present the initial notions that these students harbored around “computers,” that were gleaned from the online discussions.

3.1.2 Results

The various prompts elicited varying amounts of engagement and responses. It is worth noting that DP2 and DP3 were posted almost at the same time. In response to the discussion prompts, DP1 had 69 posts, DP2 had 45 posts and DP3 had 111 posts. Comments in all 3 discussions were open coded to categorize the major themes around students’ concepts of computers. The following broad categories emerged in DP1—

- Students who argued that only what we call a **computer** in everyday parlance, is a computer; these students argued using attributes such as size to support their point
- Students who argued around broader uses and functions to categorize computers; these students cited definitions from around the internet to justify their stance, and also saw parallels in the types of things accomplished between traditional computers, tablets and smartphones

Roughly 50% of the 69 posts were off-topic or comprised exchanges between the students that did not make a material contribution to the discussion. About 1/3rd of the meaningful comments were in category (a) above and almost all of the remainder were in (b). Table 1 describes how the discussion in response to DP1 started and how it ended. The exchanges reveal the 2 broad categories. They also reveal how, over the process of about 70 comments, students with vastly opposing stands began to

converge somewhat at a consensus that things like size did not matter, nor what we call a computer, rather it was features and capabilities that defined what is or is not a computer. They also reveal that some students continued to have trouble seeing “computers” in a broader sense.

Table 1. Exchanges from start and end of DP1

DP1 discussion starts with this exchange
S1: Computers are the only thing that should be called a computer
S2: I disagree with S1 because computers can be other things
S1: I disagree with S2 cuz phones aint computers
S3: Smart phones are basically computers. They can process data almost as fast, and they have most of the features of the computer(ie: they can send emails and can run apps). The only thing that's different is the size and shape of them
S4: I agree with S3
S5: Not exactly tho
S6: We all have our opinions, But I honestly think COMPUTERS ARE COMPUTERS
S7: Agreed
S8: Actually, phones ARE computers because they do store data like what time our orthodontics appointments are at, and doctors appointments, what time we have to get up for school, ext.
DP1 discussion ends with this exchange
S2: Computers are bigger than phones, tables, and iPods
S8: I think they're all the same, just they come in different dimensions(sizes and shapes).
S9: I dont think they are computers for reasons as they can download different apps, computers can hold and use better apps also for computers you need internet and there is no 3g or 4g
S8: But isn't that what computers, iPads, and iPhones all do?
S10: it can help you do things and will help you do homework
S7: Yes, they can all be referred to as computers
S2: Computers come in many shapes and sizes
S6: i think that they can be called MINI computers IN A WAY
S11: I also think that they can be referred to as computers. They're all the same and all do the same things. Every time someone comes up with something new, they just make it look better, and everyone thinks its "so cool" cause it just brand new. ><
S12: I would say laptops, ipads, tablets, & smartphones are all computers; I was told a computer is anything electronic that can process and store data (and preferably connect to the internet)
S3: om'put-er kam'pyootar/ noun 1. an electronic device for storing and processing data, typically in binary form, according to instructions given to it in a variable program. -Taken From Google Definitions-
S13: I was just about to say that
S14: I think computers and smart phones are different but still similar in some ways. They are different because you can use computers for more stuff like working on homework and writing computer programs. They are similar because they can both use the internet, play games, and watch videos.
S15: I think computers are everything that can store data and process information but because phones and iPads have different added functions they are given different names so we don't really think of them as computers.

It is interesting to note how students such as S6 come around to seeing devices such as phones and tablets as “MINI computers IN A WAY.” However, it is worth noting that even the students whose comments were categorized in (b) were somewhat confused at various other points during the discussion. For example, S2 and S19 had the following to say (respectively)—“*Phone's are like computers but not computers because with computers u can do more stuff.*” and “[*phones and tablets*] kinda are computers but smaller versions but some can't do certain

things that normal computers do tho.” Phrases such as “normal computers” and “like computers but not computers” suggest that since only certain devices are **called** computers while others that we’re trying to characterize as computers, are not, the question itself may be problematic to think through.

Similar analyses of DP2 and DP3 revealed that common areas of confusion among these students stemmed from what features are needed for something to be a computer. Ability to connect to the Internet and/or have Wi-Fi triggered many exchanges between students. Close to 38% of all (meaningful) comments in DP2 and DP3 were related to whether Wi-Fi was a necessary feature. About 33% spoke of definitions of computers in the abstract (e.g. a device that can be programmed to carry out instructions); 13% mentioned components of computers (memory, hard disk, screen, etc.); and another 13% also referred to computers in terms of the tasks they do to help us (“saving photos”; “helping with homework”). The broad themes of the discussion revealed two main sources of confusion. (See Table 2).

1. Connectivity– Wifi and access to the internet was seen by many students as a key criterion for a device to qualify as a computer.

2. Uses– Can a device or appliance that clearly has other main functions (such as a car, microwave, TV, thermostat, ATM) be a “computer.”

Table 2. Example exchanges from DP2 and DP3

Comments From DP2
S18: Everyone keeps saying that internet connection capabilities are necessary for a computer to be called a computer. I think that if you took a normal computer and never connected to the internet, i think you could still do a lot with it.
S16: Internet is NOT a criteria for being a computer. Neither is typing, as there are other ways to input data.
S1: Computers must store and process data as well as save photos and access the internet
S7: Bottom line is, anything that can store and process data and/or software is a computer. A desktop is a computer, an iPod is a computer, a laptop is a computer, an iPad can be a computer, a robot is a computer, a calculator is a computer, a GPS is a computer; anything that is related to the following is a computer.
Comments from DP3
S8: In my opinion, TVs aren't computers because they don't provide access to the internet, they let you watch the game tonight rather than let you surf the web.
S16: Does internet access have be a criteria?
S17: I don't think internet should be criteria.
S6: it should be a criteria
S6: i dont know why i just feel like it shouldd be. It just feels like every single device im on doesnt feel like a real computer without it because we depend on it so much nowadays, like to communicate, get work done, entertainment, etc.
S7: Everything except the microwave and the thermostat are computers.
S13: I think both the microwave and the thermostat are computers because the store and process information.
S12: How do they store info?
S16: It depends. Digital thermostats could conceivably be modified to store information (past temperatures), and some microwaves could "remember" settings. But then it becomes a question of whether that is a computer or a thermostat connected/monitored by a computer.
S7: Very true, I think that then they are just monitored by a computer and not really a computer themselves.
S1: I just don't feel like an xbox, PS, wii and non smart phones are computers they don't do things computers do. They do some of the stuff computers do but definitely not all of it

3.2 High School Student Conceptions

3.2.1 Participants & Procedures

The sample comprised 117 children from 9th and 10th grade enrolled in a year-long ECS course in a large urban school district in a Midwestern state in the U.S. IRB consent and assent were sought from parents and students. Data was not used from students who did not provide consent.

As mentioned in Section 2, the ECS curriculum is broken up into several units each of which build on ideas from previous units. The first unit, “Human Computer Interaction”, provides an introduction to several topics related to computer science. The goals of Unit 1 include providing students with an introduction to the concepts of computers and computing, the worldwide web, the concept of data, and implications of different forms of communication. End-of-unit assessments were developed for the first four ECS units, as well as one additional cumulative assessment that covered concepts from all four units [20, 22]. The results discussed here are based on an analysis of student responses to one question on the Unit 1 end-of-unit assessment. The question provided students with a brief description of a microwave and then asked students to provide an argument for whether or not a microwave was a computer. We expected students to first identify a characteristic of a computer and then to explain why a microwave did or did not have that characteristic.

In the cumulative assessment, we took a different approach and instead of asking students to explain why something was a computer or not, we provided the students with a task. In this case designing and printing something using a 3-D printer and asked students whether or not the task was an example of computing, and if so, what aspect of the 3-D printing process was an example of computing. For both questions, points were assigned based on the explanation and not whether the student was able to correctly say if the task was or was not a computer or an example of computing. For the Unit 1 question, misconceptions of a microwave did not count against the students’ score.

3.2.2 Results

On the Unit 1 assessment question, approximately 90% of students indicated that they believed a microwave was a computer. However, only about 2% were able to list two characteristics of a computer and appropriately relate them to a microwave. Examples of characteristics that we were hoping students would identify were—accepting inputs (to carry out a function—of heating food for a certain amount of time), producing outputs (based on inputs), storing information, and carrying out commands/processing information.

Table 3 lists a sample of responses that reveal that students had not completely understood the target concept. They identified characteristics that computers have but we did not believe they were *key* to the idea of computing and for something to be identified as a computer. The first four responses mention characteristics that a “typical” computer such as a desktop or laptop would have, but they are characteristics that not all computers have, or that objects that are not a computer may have. For example, an analog clock can display information, and a lamp uses electricity but we would generally not consider those to be computers. These responses show students focusing on trying to figure out what a microwave and a “typical” computer have in common, versus a broader view of computing and key features of

computing devices. While most students answering “yes” for “Is a microwave a computer” indicates that students learned to broaden their definition of computers, it is not clear that students gained a deeper understanding of computing and computation.

Table 3. Example responses to ECS Unit 1 assessment

Response	Computer Characteristic	Explanation
R1	Uses electricity to function	Most, if not all, computers function by using electricity as a source of energy
R2	Pre-set buttons	Has buttons like a computer that you can push how you think you want your food cooked
R3	Displaying Information	The microwave displays the amount of time remaining when it is in use.
R4	Screen	Microwaves and Computers both have screens. They are similar.
R5	Understands Math	A microwave understands if you press the button “add a minute” which is microwaves, it will add a minute to the original time.

Table 4. Example responses to ECS summative assessment

Response	Explanation
R6	It is a computing task because you have to design something and designing is part of computer science.
R7	It takes in data in the form of a virtual image then changes it into a physical mold.
R8	3-D printing is an example of a computing task because it was specific steps to achieve a goal. The printer does a step one by one in order just like a computer program would.
R9	Creating a 3-D object is an example of a computing task because you’re using programs in the computer that tell weather or not or how you want the object to look.
R10	3-D printing is an example of a computing task because it uses a computer to tell the printer what to do.

In R5, the student was making a connection between computers and mathematics. It is interesting to note that one of the goals of the unit is for students to gain an appreciation of the connection between mathematics and computer science. In this case, the student may also be thinking of a computer as something that computes and therefore discusses what it is that a microwave might compute. While one can see the effort to think of the aspects of computers beyond the physical aspects, the explanation falls short in that it isn’t clear why “understands math” is an aspect of a computer. These examples highlight that students can come away from discussions about what a computer is without a clear understanding of key characteristics that warrant something being called a computer.

On the cumulative assessment, students were asked to explain why or why not 3-D printing was an example of a computing task. Some example responses are listed in Table 4. Only R6 indicates an understanding that computing was something beyond just the use of computers, and the idea that design is part of computer science. Responses R7 and R8 were more typical responses, as they related the 3-D printer process to the characteristics of a computer. In R7 the student described the process as taking input and producing output, while in R8 the student describes the process as that of following specific instructions. The last two responses suggest that some students believe that an example of a computing task is one that uses a computer.

In general, these responses are closer to the connections we hope students will make in an introductory CS curriculum as opposed to their responses for why a microwave is a computer. We also prefer the re-framing of the question to ask students about a “computing task” rather than whether an object is a “computer.” This re-framing appears to encourage students to answer based on uses and not on the physical aspects of a computer.

4. DISCUSSION

The results for the middle school discussion highlight the value of the inquiry-driven curriculum. An approach such as this (and that ECS uses) builds off of socio-cultural learning theories that acknowledge that learning does not only occur in a vacuum; that students bring bodies of knowledge from their lives to the classroom. This includes preconceived notions that must be engaged. Doing so also helps teachers identify students’ misconceptions—a first step in helping learners rectify them.

It is indeed fascinating to see students’ thinking evolve in the online discussion to looking at characteristics as the defining criteria and deliberate what is or is not critical for a computer to perform different types of functions. That said, they show that the focus on *calling* something “a computer” (that is not a desktop or laptop computer) is problematic for students; they start to refer to certain things as “normal computers”, especially when discussing other things that are not normally called computers, because the question forces them to argue whether or not other objects are “computers”. High school students’ performance in assessments dealing with this topic also reveals the same issue.

Students appear to have a conception of a computer, and even when they are asked through discussion to broaden this conception, the distinctions between general-purpose and special-purpose computing devices is not always apparent and they are unable to identify *key characteristics* of devices that enable computing. This is perhaps at the core of why some students in middle school struggled with the question, and spent so much time debating whether being able to access the internet was necessary for a device to be a computer. It is also why the high school students struggled with “*Is a microwave a computer?*”.

The different ways to conceive of a computer have led us to refine our ECS Unit 1 assessment question by providing the characteristics of a computer we would like students to focus on in their explanation. Upon reflection, we decided that it wasn’t as important for students to remember a particular set of characteristics but more that they could take a set of characteristics and determine whether or not they enable computing. With the reworked item, we are shifting focus on *computing* rather than the *computer*.

One concern that we have after viewing the responses on the cumulative assessment is that some students did not seem to gain an appreciation of computing separate from a computer, and felt a device was involved in computing only because it used a traditional general-purpose computer. It may be the case that the discussion of computing (which came after that on computers) was framed or defined by the discussion of what makes a computer, and more time is needed to having students understand computing and computation rather than computers.

4.1.1 Rethinking the question to reframe the computer-centric conversation and mindset

Fellows and Parberry [2] famously said about getting kids excited about CS, “What would we like our children, the general public of

the future, to learn about computer science in schools? We need to do away with the myth that computer science is about computers. Computer science is no more about computers than astronomy is about telescopes, biology is about microscopes or chemistry is about beakers and test tubes. Science is not about tools; it is about how we use them and what we find out when we do.”

The name “computer science” itself is problematic [17] since (a) computer science is not simply the “science of computers”, and (b) it leads to a misplaced fixation with computers. There have been countless articles written about this, and also moves to rename the discipline. In European universities, it is typically referred to as ‘informatics’, and “[to] avoid using the name of the machine in the title, [...] some use the word ‘computing’ instead” [3]. Not surprisingly, it has been shown in studies that student’s misperceptions of computer science stem from these extremely “computer-centric” notions of the discipline. A majority of middle school children erringly think computer scientists mostly “build or fix computers”, and some curricula make a concerted effort to draw children away from the machine-centric view of discipline to see computing in a broader light [7, 8].

How wise then is the decision then to start a curriculum focused on the big ideas of computing with the narrow question “*what is a computer?*” After all, is it so surprising that students in middle school call out on the absurdity of the question “is a microwave a computer?” It’s not entirely illogical for a student to turn around and follow up that question with “*Why is a microwave called a microwave then?*” The problem lies in conflating the features of a device that uses computing to perform its functions with the object that we in everyday parlance identify as “computers”. When asked to define a computer, one student in our middle school sample responded, “A screen with a keyboard that has a logo that says mac and pc,” exemplifying this view.

CS is at its core a study of problems, problem solving, and the solutions that come out of the problem-solving process that can be carried out by a computational machine, and systems the bring together hardware *and* software to make this possible. We believe the focus should be on **computing**, **computation** and **computability**, not the **computer**. It would be less confusing for students if they were expected to focus on *aspects of computing that are in use in the many digital devices that we do not even call computers* without phrasing the question as *Is X a computer?* We hypothesize that introductory curricula would be better served, with the question *What is computing?* and *How is computing used in different devices and appliances, as well as in the ways in which we do so many of our day-to-day activities such as communicating and collaborating?* “*What is computation?*” and follow up questions such as “*Can we say that the human body does computation?*” may also lead to rich thought and conversation. Even the ECS curriculum cites “what is computing?” as “possibly [the] more pertinent question” [9]. The discussion could also delve into what computer scientists do (hint: not all of their work involves programming or even computers!). This would help students get a better sense of the types of diverse fields and industries that computer scientists support. While we do think the discussion of “what is a computer” is important, this discussion might be better served once students have a broader understanding of computing and computation. An inquiry-based discussion around these more pertinent questions could be guided to include a discussion on key features of digital devices that make computing possible, and it is well within reason to assume that a robust discussion on the topic would organically also

include a debate on features of computers. These hypotheses would need to be empirically tested.

5. CONCLUSION

This paper reports on middle and high school students' engagement with and understanding of the question "what is a computer?" Our findings indicate that the question (a) places a misplaced focus on the *computer* (rather than computing or computation) and (b) triggers confusion when students are expected to apply the definition to other devices and appliances. One of the goals of an introductory CS course is for the students to gain an appreciation of the discipline and to recognize that CS is more than just programming or using a computer. We are concerned that "What is a computer?" is the wrong starting point to achieve this learning goal as it does not do enough to move students away from thinking of computer science only in relation to computers. We want students to understand that different aspects of CS and computing are used in many different ways to solve real-world problems, model the world, and help us communicate and express ourselves. We urge educators to shift the initial focus of introductory courses to the deeper ideas of computing, computation and computability. While further research is needed to determine if our hypotheses bear out, we believe that a discussion around these ideas will likely allow students to start with a broader and more robust appreciation for CS as a discipline.

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