

# **A Qualitative Exploration of Student Preconceptions of Computational Thinking**

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A Thesis

Submitted to the faculty

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Master of Science

in

Learning Sciences & Technologies

April 2022

APPROVED:

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## **Abstract**

Computational Thinking is commonly considered an important skill to learn in today's day and age. It opens opportunities for students to find careers in STEM disciplines as well as prepare students for higher learning. However, due to there being no singular definition and thus no form of assessment or widespread mode of learning, there is a barrier to teaching computational thinking. This Master's thesis will be broken into three parts. The first part will explore the various definitions of computational thinking, why it is important, and how we have generated a taxonomy based on previous work for a content knowledge developing technology platform. The second part describes the online study, which aims to answer two research questions: 1) Do student answers largely match researcher designed intentions? 2) Which themes emerge among student responses on the items with the most and least agreement? The study that is performed on undergraduate college students and the materials that were developed will also be discussed. The third part aims to explore student responses in computational thinking from the designed vignettes as well as go over results and discussion.

*Keywords:* computational thinking, grounded theory, student responses

## **Acknowledgements**

Firstly, I would like to thank my researchers Hannah and Nellie for working with me during this whole process. We spent many hours and late nights checking over our coding. I appreciate you both putting up with my hardheadedness when it came to me defending certain code associations. This thesis would not have even been close to completed without the both of you!

To Avery, Francis, and Gillian, thank you so much for mentoring us. We were novices when it came to qualitatively coding so we really appreciate your guidance. Also, thank you for being our tie-breakers when our small group could not come to a consensus.

Thanks to Erin and the lab for all the love and support and the sheer kindness we all have for each other. Classes would never be the same without you all!

Lastly, thank you to my friends, and family for coming to my presentation and supporting me through my endeavors as I continue navigating my path. A special thank you to my partner Matt for being my ear and making sure I was ready for the day before I even left our apartment!

This material is based upon work supported by the National Science Foundation under Grants No. IIS-2041785 and IIS-2026722. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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## **Part 1: Theoretical Framework on Computational Thinking**

In this section, I will describe computational thinking and the need to incorporate it into our curriculum and education. I also describe the Wearable Learning Cloud Platform as it pertains to computational thinking and the basis for the study that will be described in part 2.

## **Why is Computational Thinking Important?**

Computational thinking is applicable to many different disciplines and areas of research and its interest within these disciplines is evident. In today's day and age, there is an increased need to learn how to interact with data as it has become an important component in education and career advancement (Weintrop et al., 2016). All of today's students will interact with computing in some way and many will enter fields in which computing is heavily involved (Barr & Stephenson, 2011), so being able to apply computational thinking skills and the interest to do so is imminent (Aho, 2012). The increases in data available as well as the increasing need to analyze this data in all facets of human exploration highlight the importance of computational thinking as a valuable skill for today's students to have. Students who are exposed to computational thinking early will be more inclined to study it later in life, are prepared for computer science courses, and can be productive members of society (Werner, Denner, Campe & Kawamoto, 2012). Moreover, computational thinking has been widely recognized by educators, business leaders, and researchers as a set of skills that can improve access to STEM careers (Smith, 2016; Weintrop et al., 2016; Adams & Pruim, 2012; Wing, 2006). However, until recently, computer science education has not typically been offered to students until high school and many schools do not even offer it, especially in schools of high minority populations (Margolis, 2008). This is also partially because few teachers have the assessment tools, training, and curricula required to teach them (Howard, 2019; Schulte et al., 2012; Tsai & Chai, 2012; Yildiz Durak, 2020). This causes a need to define computational thinking and set clear guidelines on how it can be implemented in classrooms to help educators (Weintrop et al., 2016) and mitigate these main limiting factors in implementation (Werner, Denner, Campe & Kawamoto, 2012). Students should have the opportunity to practice computational thinking in K-12 education because such skills are facets of higher-level thinking and problem solving that are applicable across a wide variety of contexts.

## **What is Computational Thinking?**

Researchers have attempted to define computational thinking through various contexts (e.g. math, science, or computer science courses in primary and secondary education) and lenses (National Research Council, 2010). To comprehend the overall idea of computational thinking, this section is an attempt to summarize various definitions of computational thinking and the context in which researchers based their definitions.

Initially, Jeannette M. Wing introduced a now well known definition of computational thinking. She broadly explains computational thinking as “the thought process in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent” (Wing, 2010). Wing explains that computational thinking is valuable and relevant in various disciplines, not just computer science; it involves an individual to think in multiple levels of abstraction as well as identify problems, inquire the difficulty of a problem, and find the best way to solve that problem (Wing, 2006).

Since Wing’s initial definition, other researchers have expanded on her idea of computational thinking and have described specific frameworks and contexts for computational thinking. One researcher, Alfred Aho, explains that computational thinking is “the thought process involved in formulating problems so their solutions can be represented as computational steps and algorithms” (Aho, 2012). He and Wing agree that abstraction is an important component to computational thinking and both do not limit the context to simply be within the realm of computer science, but far beyond. While Wing explains how problem solving is a component to computational thinking, Aho goes further to say that what differentiates regular problem solving from computational thinking is the solution to a problem and how that solution should be akin to mathematical abstractions and models, like computational steps and algorithms. An individual’s thinking should be similar to the way machines take parts that are important and dismiss the rest that can be considered useless.

Barr & Stephenson (2011) look at computational thinking as not necessarily the solution, but the *process* towards finding a solution. However, they do agree with Aho and Wing that abstraction is an important component to computational thinking. They consider using concepts like abstraction, recursion, and iteration to analyze data. Building tools can also be considered a form of computational thinking, as the tools created can be used to find a solution. They formulate their definition of computational thinking in the lens of students being tool builders; students use computational thinking as a means to keenly select what tools to use and how to use them most effectively in order to find a solution to their specific problem.

While prior definitions focus on abstract ideas, Grover & Pea (2013) reviewed the field of computational thinking in K-12 education, focusing on applications to the classroom. They believe that computational thinking is thinking similarly to a computer scientist when confronted with a problem. They began to see several key elements emerge in the area of computational thinking: abstraction and pattern generalizations, systematic processing of information, symbol systems and representations, algorithmic notions of flow of control, structured problem decomposition, iterative, recursive and parallel thinking, conditional logic, efficiency and performance constraints, and debugging and systematic error detection. They argue that there needs to be attention to assessment of computational thinking knowledge and ability if there is intention to integrate computational thinking into K-12 classrooms. However, they could not identify whether computational thinking should be its own subject or immersed into other subjects.

After Grover & Pea, Shute, Sun & Asbell-Clarke (2017) also followed along the context of introducing elements that involve computational thinking. They define computational thinking as, “the conceptual foundation required to solve problems effectively and efficiently (i.e., algorithmically, with or without the assistance of computers) with solutions that are reusable in different contexts.” They argue that many problems across technological and non-technological settings can be approached effectively with computational thinking. Their lens differs from previous researchers as

they do not require the solution to a problem to be computable. Similarly to Grover & Pea, they mention the importance of creating an assessment that can measure gains in computational thinking skills. If this is not developed, then they argue it would make it difficult to incorporate computational thinking in education.

Weintrop (2016) proposed a definition and taxonomy of computational thinking based on conceptual commonalities identified in their own definition as well as from other researchers with a focus on providing concrete examples, particularly for science and mathematics. Weintrop's taxonomy identifies the following constructs of computational thinking: data practices, modeling and simulation, computational problem solving, and systems thinking. Data practices include collecting, creating, choosing data representations, manipulating, analyzing, and visualizing data. Modeling and simulation is seen through interpreting, assessing, designing, and constructing models as well as using models to test solutions. Computational problem solving encompasses preparing a problem for a computational solution, programming, choosing computational tools, assessing solutions to problems, creating modular computational solutions, creating computational abstractions, debugging, and iteration. Systems thinking is seen through by viewing systems as a whole, describing relationships, thinking in levels, similarly to abstraction and generalization, defining systems, and decomposition. Their goal was to provide a classroom-ready definition that drew on existing computational thinking definitions and practices while incorporating concepts focused in math and science contexts, better preparing students to potentially pursue careers in these disciplines.

In our research, we used Weintrop's taxonomy as an overarching theme that explains computational thinking. We have found that other prior work can be seamed into Weintrop's taxonomy (Castro et al., under review). For example, data practices involve processes of working with a compilation of measurements or observations through the collection, creation, manipulation, analysis, or visualization of data (Weintrop et al., 2016). Shute et al. (2017) talk about data practices involving data collection and analysis in a K-12 setting. These perspectives on the use of data as an integral aspect of computational thinking often come from contexts that involve programming to automate

the analysis of data, especially as new computational tools for collecting, analyzing, and visualizing data are increasingly used in classrooms (Foster, 2006; Weintrop et al., 2016).

Moreover, Weintrop et al. (2016) defines models as simplifications of reality that highlight or approximate features of a phenomenon. The ability to create, use, and assess models and simulations deepens conceptual understanding by challenging students to understand and create representations (Weintrop et al., 2016; Shute et al., 2017). Weintrop identifies modeling practices used in mathematics and science, such as the use of flowcharts, diagrams, and physical models, as well as creating computational models and simulations to be run on a computer. Others also consider algorithms themselves as models, and the creation of these algorithms and programming them on a computer as concrete instances of creating models and simulations (Grover & Pea, 2018).

Furthermore, systems thinking includes practices such as investigating a complex system as a whole, understanding relationships within a system, thinking in levels, communicating information about a system, and managing the complexity of systems (Weintrop et al., 2016). Shute et al. (2010), in their study of systems thinking through immersive games, refers to systems thinking as the ability to understand various relationships among elements in a given environment, which aligns with other researchers' conceptions of systems thinking. Similarly, though not explicitly called "systems thinking", Wing (2006) referred to "using abstraction and decomposition when attacking a large complex task or designing a large complex system" as a cognitive process involved in computational thinking. Abstraction emerges across literature as an essential cornerstone of computational thinking, where it is understood as a way of defining patterns and being able to generalize from particular instances or information, which can be viewed under the systems thinking lens (Grover & Pea, 2013). Importantly, these definitions of systems thinking have emerged across different K-12 contexts (Shute et al., 2017) demonstrating the wide range in which students can be engaged in this practice.

Computational problem solving also emerges as a theme across many definitions of computational thinking and is typically defined as the process of reaching solutions for

issues that use computational thinking (Shute et al., 2017; Weintrop et al., 2016). Shute (2017) argued that problem solving is at the heart of computational thinking, however, Weintrop et al. (2016) considered problem solving as one of four core components of computational thinking. Meanwhile, Wing (2010) did not provide concrete examples of, or contexts for, computational problem solving; instead, broadly addressing the process as, “reformulating a seemingly difficult problem into one we know how to solve, perhaps by reduction, embedding, transformation, or simulation.” These perspectives on computational problem solving, the processes involved, and their relation to computational thinking, emphasize that researchers share similarities on the broad construct while retaining small differences that might be a result of the context of their work.

These definitions reflect some of the different conceptualizations through which researchers and educators have understood and defined computational thinking over the past several years. We initially attempted to map these definitions and constructs to the Wearable Learning Cloud Platform developing our own conceptualization of computational thinking that is specific to the platform. We describe the Wearable Learning Cloud Platform and its relation to computational thinking in the following section.

## **The Wearable Learning Cloud Platform**

The Wearable Learning Cloud Platform, also known as WearableLearning, is a STEM content knowledge developing technology platform that enables teachers and their 5-12th grade students to play, create, debug, and manage multiplayer mobile technology-based games (Arroyo et al., 2017; Micciolo, 2018). WearableLearning supports collaborative, interactive, and gamified experiences for full classes of K-12 students and teachers, where the ecology of the classroom embraces mobile technologies that are familiar to kids. WearableLearning provides students with opportunities to develop an understanding of computational thinking concepts by visually programming games modeled as finite state machines, a topic typically reserved for higher level education (Hopcroft & Ullman, 1979). Finite state machines are computational models that can be used to simulate phenomena, sequential logic, and the behavior of computer programs. The WearableLearning curriculum steps students from the design to the implementation and deployment processes of their games (Castro et al., under review). The technology guides and supports students as they manipulate objects available in their physical environments (e.g., to take measurements, make computations, estimate variables, or gesture using their bodies), all while interacting with their peers, teachers, and technology, in rich discourse. As players, students participate in games that involve problems from relevant curriculum, reinforcing subject knowledge. As creators, students and teachers engage with computational thinking practices and concepts by considering how to design engaging games for their peers, how to blend STEM material into games based on their own knowledge, and how to specify game mechanics thoroughly by describing and programming the behavior of the devices. WearableLearning's game-editing platform enables the creation of multi-player game experiences, allowing game creators to program different behaviors for players and teams.

As part of a team, we have successfully deployed our work to roughly 500 5-12 grade students and roughly 25 STEM educators. We conducted studies to investigate whether and how math games created with WearableLearning can be integrated into

STEM classrooms to promote mathematics learning (Smith et al., 2020, Arroyo et al., 2021; Casano J.D.L., Tee H., Agapito J.L., Arroyo I., & Rodrigo M.M.T., 2019; Agbaji, 2018). Fully-fledged games have been created by teachers, students, and researchers using WearableLearning. In these studies and games, I qualitatively coded gestures and analyzed that data, comparing college students with elementary school students, as well as created content to display the games that were already created.

Computational thinking at the K-12 level is a relatively new concept, yet it includes much more than just coding (Weintrop et al., 2016). Some computational thinking concepts and practices involve problem decomposition (e.g., breaking problems down into sub-problems), identifying patterns of behaviors, representing different forms of data (forms of inputs, object identifiers, outputs, etc.), thinking at different levels of abstraction (stepping back to understand a full picture of a solution, black-boxing details as a way to simplify and manage complexity), specifying algorithms, evaluating solutions, and iterative refinement (Grover & Pea, 2018). Students can learn these skills as they create and play games such as the ones that WearableLearning supports.

All students should have the opportunity to learn and practice computational thinking in school. WearableLearning provides opportunities for K-12 students and teachers to develop computational thinking skills through a low-barrier entry point for gameplay and game design, both through the platform and curriculum. WearableLearning provides a platform that allows teachers and students to exercise computational thinking, a process at the intersection of engineering design, problem solving, and iterative design processes. Students engage in this cyclical process by playing and iteratively designing games in WearableLearning. For instance, students and teachers must anticipate, articulate, specify, program, implement, test, and revise at a high level of detail all possible moves that a game player could take within each game. Additionally, they must simultaneously consider the interactions between multiple players, the STEM concepts the game is about, physical materials, as well as spaces in the environment. Our current challenges are two-fold. First, one challenge is also a motivation behind this project: many K-12 teachers are often not comfortable with using technology or teaching

computational thinking in the classroom. Prior research has indicated barriers that teachers face in integrating technology into their classrooms (Ertmer, 1999; Tsai, & Chai, 2012). To break these barriers, teachers need more opportunities to experience working with technology and design processes to appreciate the challenges and thinking that are required to develop effective games for student learning. As such, we need to train teachers to implement technologies to positively shift their confidence in the importance, value, and relevance of computational thinking in their students' future success. Another challenge is assessing how students and teachers develop computational thinking skills in the process, as there is not a general agreement on the boundaries of computational thinking, nor how to assess it broadly. To that end, we have created a framework of what, when, and how computational thinking occurs within the WearableLearning curriculum (Castro et al., under review).

## **Part 2: Computational Thinking Vignette Study**

While we have shaped a taxonomy to encompass the lens of WearableLearning, it still does not attempt to solve the issue of finding a generalized assessment of computational thinking. We recognize that students may be able to recognize computational thinking in practice but not have the vocabulary to articulate why. We designed 12 vignettes in a variety of contexts to see if students can identify examples of computational thinking, and explain their reasoning in an open response. These vignettes included both situations involving technology and without technology, in both academic/professional and everyday settings. Our intention is not to validate the vignettes as assessment material for classrooms, instead it is to recognize the ambiguity and explore the student responses in how *they* identify what computational thinking is.

From this study, we aim to answer these research questions: 1) Do student answers largely match researcher designed intentions? 2) Which themes emerge among student responses on the items with the most and least agreement?

## **Study Methods and Procedures**

### *Participants*

Online survey responses were collected from 37 college participants from a Northeastern technical school. Only 35 participants fully completed the survey, but due to the nature of our research questions, each response will be analyzed. The survey was administered online through Qualtrics, a study participation platform. Demographics were not collected.

### *Procedures*

An online study was deployed in early 2021 for 7 weeks. Participants first had to view the consent form and by electronically signing the form they agreed to continue with the study with IRB approval. All responses were anonymized and no identifying information is associated with any participant. Participants were instructed that they would be presented 12 short descriptions of different situations. In each vignette, participants had to select “yes” or “no” in whether or not the following was an example of computational thinking and then were prompted to write a brief description explaining their answer. Once completed, participants were given a debriefing form and compensated with course credit for their psychology class requirement.

### *Materials*

See below for the vignettes.

## Study Vignettes

Participants were prompted to answer the question, “Do you think the following is an example of computational thinking?” for 12 personal vignettes. These vignettes were created similarly to how computer scientists use narratives to portray more ambiguous concepts for learners.

Four vignettes were created with the intention of not embodying components of computational thinking to see if participants were able to recognize the distinction. The other eight are intended to embody one of the four components of computational thinking based on Weintrop’s taxonomy. In our design process, we also wanted to include vignettes that do not explicitly contain the use of technology, as many researchers have recognized that technology is not an ingrained component to computational thinking skills. While these were the intentions in designing the vignettes, we as researchers do recognize that the vignettes can be ambiguous and thus can be interpreted another way than we intended and therefore others can conclude to a different solution. However, we are more interested in participant explanations rather than the validity of the vignettes themselves. The vignettes and the computational thinking components they embody are seen in the table below.

| Computational Thinking Components | Vignettes                                                                                                                                                                                                                                                                             |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Not Computational Thinking        | Cole takes a walk at the park each day at 8 am. He walks exactly 2 miles and it takes him exactly 30 minutes to finish his walk. He observes the same golden retriever each day by the water fountain at 8:15 and observes the same man turning off the park lights each day at 8:05. |
|                                   | Luisa just finished her senior capstone project in psychology. As part of the project, she watched online interviews and typed up transcriptions from 50 participants’ interviews.                                                                                                    |
|                                   | In his free time, Matt enjoys cooking                                                                                                                                                                                                                                                 |

|                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                        | <p>Italian pastas. After following the instructions of each new recipe that he tries, he notes how much he enjoyed the taste of each dish.</p>                                                                                                                                                                                                                                                                                                                                                                             |
|                                                                                                        | <p>Lily wants to make sure she gets all of her assignments done this school year. She decides to buy a planner and write down each assignment on the day it is due.</p>                                                                                                                                                                                                                                                                                                                                                    |
| Computational Thinking Skill: Decomposition with technology (Rich) and no technology (Hannah) included | <p>Rich and his three friends decided to write a simple calculator computer program. They decide to split the task so that one person writes a program for each of the mathematical operations of adding, subtracting, multiplying, and dividing, and then put the separate programs together after they've written each.</p>                                                                                                                                                                                              |
|                                                                                                        | <p>Hannah is trying to decide whether or not to attend graduate school. As she weighs her options, she tries to visualize what factors impact her decision by making separate lists for each of her current responsibilities, interests, and possible drawbacks to attending graduate school.</p>                                                                                                                                                                                                                          |
| Computational Thinking Skill: Iteration with technology (Olivia) and no technology (Grace) included    | <p>Olivia wants to start a car-sharing company. To get her business off the ground, she knows that she needs a good website to attract customers. Olivia originally designed her website in Google Sites then asked her family and friends for feedback. She took their feedback and edited the site, then asked for feedback from her friends on Facebook. Now, Olivia is editing her website based on that feedback and is hoping to send out a survey about the website to family, friends, and friends of friends.</p> |
|                                                                                                        | <p>Grace received a recipe for bread from her mom. She followed the recipe but wasn't happy with how the loaf turned out. Since then, each time she uses the recipe, she tweaks the amount of one ingredient listed to see how she can improve the recipe.</p>                                                                                                                                                                                                                                                             |

|                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                         |
|-----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                       | <p>Preschoolers track the growth of their classroom plant. Each day they measure the height with a ruler and record that height in a notebook. They also draw daily pictures of what the plant looks like. On day 20 they compare their notes to see who's plant is the tallest.</p>                                                                    |
| <p>Computational Thinking Skill: Data Practice with technology (Coffee) and no technology (Preschoolers) included</p> | <p>The local coffee shop owner wants to know how many customers she has on each day of the week to help her plan staffing. She graphs the daily cash register purchases in a histogram on excel and uses this to conclude that she has the most customers on Wednesdays. She decided to add an extra barista on Wednesdays to cover the busy crowd.</p> |
| <p>Computational Thinking Skill: Debugging with technology (Francis) and no technology (Plumber) included</p>         | <p>Francis has a robotics assignment due tonight but his code isn't working! He decides to go line by line checking to see if he has any errors until his robot starts moving again.</p> <p>A plumber is fixing a pipe. There is a hole somewhere and he must find it. He inspects the pipe section by section until he finds the hole.</p>             |

## Part 3: Computational Thinking Coding Scheme and Results

To find commonality and to explore overarching themes in student perceptions of computational thinking and what they believe is considered computational thinking or not, we qualitatively coded the student responses in three iterations. Three researchers participated in this work. In explaining the positionality of the researchers, two were graduate students experienced in computational thinking and one was an advanced high school student. We used a grounded theory approach to find emergent codes that presented themselves when combing through the participant responses. Due to the grounded theory's cyclical approach, it is difficult to reliably produce intercoder validity (O'Connor, C., & Joffe, H., 2020). Through the grounded theory approach, we derive our theories and ideas from the data itself, not from a previously validated coding list. This approach is helpful in work like this as computational thinking does not have a standardized qualitative coding list. This coding took over 5 months of weekly meetings as well as several hours of individual work between each researcher.

In our first iteration, we wanted to see general themes that emerged from the responses. In this case, we individually looked at responses and noted down frequently recurring words or general ideas participants were attempting to describe. Each researcher tackled this first iteration in various ways. I noted down the frequency of words that appeared in the participant responses. Other researchers highlighted subsections of responses where they noticed overarching themes and presented them as codes. A few of the original codes we curated are seen below.

| Code          | A Rough Definition                                                                                             |
|---------------|----------------------------------------------------------------------------------------------------------------|
| Collaboration | When participants mention the character either dividing work with others or working together with someone else |
| Checking      | When participants mention the character examining something to corroborate its accuracy                        |
| Decision      | When the participant explicitly mentions "decision"                                                            |

|                     |                                                                                                        |
|---------------------|--------------------------------------------------------------------------------------------------------|
| Identifying Problem | When the participant mentions finding an issue                                                         |
| Information         | When “information” is explicitly mentioned                                                             |
| Process             | When the participant mentions steps that need to be taken to reach some sort of end goal               |
| Quantification      | When the participant mentions the subject of the vignette adding a numerical value to an abstract idea |
| Sequencing/Creating | When the participant explicitly mentions “creating”                                                    |
| Time                | A participant mentioning time, either the time of day, a future event, frequency, etc.                 |

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Once each researcher curated their individual code lists, we met as a group. We compiled the lists and formed one large list. In this instance, we did not remove any themes or codes in an attempt to not influence the list with our previous knowledge on computational thinking.

In the second iteration, using the new list, we broke the coding into parts by each vignette. We individually reviewed the participant responses of one vignette, noting down when a code presented itself in a response. After coding all the responses to one vignette, we met as a group to discuss discrepancies and agreeances. Once we were in full agreement, we would move on to the next vignette and its responses and repeat the cycle until all the vignette responses were all re-coded.

In the final iteration, after re-coding all the responses, we reexamined the list of codes we curated in the beginning. We noticed that there were codes that were never or very rarely used in the end. In this case, we eliminated these codes. In this iteration, we also defined each code. Recognizing that words or phrases can have multiple meanings, we wanted to concretely define how we used each code. Through defining, we also eliminated codes that we felt like they did not contribute to effectively understanding how participants interpreted what computational thinking is.

Below is the final table of 38 codes that were kept with how we defined them and the participant examples associated with each code. Notice that phrases can have multiple codes associated with it, therefore the same example can be in different codes.

**Table of Codes with Definition and Examples.**

| Code               | Definition                                                                                                                                               | Examples                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Abstraction</b> | Discussion of reducing complexity by removing unnecessary information or focusing only on relevant information or explicitly using the term abstraction. | <ul style="list-style-type: none"> <li>• “She had a problem and broke up how to find a solution. She then <i>took the important information and implemented it</i> into her solution idea.”</li> <li>• “She <i>took in very useful data from her customers</i> and improved her work schedule in response”</li> <li>• “Using <i>abstraction</i> and algorithms to get to a solution.”</li> <li>• “Yes because she is breaking the problem down, <i>taking only the information she needs</i> to find out how many customers come in on certain days.”</li> <li>• “Francis doesn't have to go line by line - he can <i>deduce which parts of the code could be giving the robot trouble</i> and start from those sections of his code”</li> <li>• “Following a recipe is CT at its core, and she is changing it to <i>include new ideas important to her</i>.”</li> <li>• “Grace <i>isn't trying to narrow down the ingredients that could bring the best results</i> - she is trying every single combination which isn't efficient at all.”</li> <li>• “I believe this might be an example of <i>abstraction</i>”</li> <li>• “Yes she is separating the idea into parts and <i>recognizing important factors of each part</i>. Taking out the valued information.”</li> <li>• “This is decomposition and <i>abstraction</i>”</li> <li>• “She is not creating patterns, <i>recognizing important information</i>, or working with an algorithm. She is just following basic steps to complete a project.”</li> <li>• “Following a recipe is CT and rating dishes is <i>extracting important information</i>.”</li> <li>• “This is definitely <i>abstraction</i>”</li> <li>• “Olivia <i>isn't trying to come up with the most efficient and abstracted way</i> to improve her website - she is asking for feedback in a number of batches instead of trying to ask for it all at once in the most effective way possible.”</li> <li>• “He works in part to find his solution. He is <i>looking for something to stand out in each section</i> that would indicate the need for a certain solution.”</li> </ul> |

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| <b>Algorithm</b>             | Explicit mention of the term “algorithm”.                                                                                         | <ul style="list-style-type: none"> <li>• “Using abstraction and <i>algorithms</i> to get to a solution.”</li> <li>• “She is not creating patterns, recognizing important information, or working with an <i>algorithm</i>. She is just following basic steps to complete a project.”</li> <li>• “maybe? editing something according to feedback could be done <i>algorithmically</i>”</li> <li>• “She uses both decomposition and <i>algorithms</i> to create a plan for her to make her website”</li> <li>• “This situation with Olivia demonstrates Computational Thinking because as Olivia is making her website she is most likely using <i>algorithms</i> or different problem-solving techniques to get to her end goal.”</li> <li>• “They are recognizing the situation, breaking it into parts and steps, then solving based on each step to put it together at the end. It is an <i>algorithm</i>.”</li> <li>• “This definitely indicates Computational Thinking because developing codes and <i>algorithms</i> requires proper calculations, therefore involving proper computations.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Analyzing Information</b> | When the participant mentions using, processing, analyzing or assessing information or mentioning coming to an informed decision. | <ul style="list-style-type: none"> <li>• “Absolutely! The coffee shop owner is quite literally <i>computing the average amount of customers per day to help her understand how to better support her business</i>.”</li> <li>• “because she is collecting data and <i>analyzing</i> the data logically”</li> <li>• “She <i>analysis</i> the input to project an output plan.”</li> <li>• “She <i>analyzed</i> her data in order to come up with her next decision”</li> <li>• “She gathers data and <i>analyzes</i> it.”</li> <li>• “She is able to <i>analyze</i> the data to make a logical decision”</li> <li>• “She is <i>analyzing</i> data and uses that data in a way to solve a problem or improve a system. It requires more thought process and creativity”</li> <li>• “<i>She made a graph to see how many customers she gets on certain days</i>”</li> <li>• “she takes down data, thinks about it, and <i>makes a decision and action based on the data</i>”</li> <li>• “The coffee shop owner tracked patterns and <i>came up with a solution for a busy day of the week</i>, demonstrating computational thinking”</li> <li>• “<i>using info collected to change her plan</i> for the coffee shop”</li> <li>• “Yes because she is breaking the problem down, taking <i>only the information she needs to find out how many customers come in on certain days</i>.”</li> <li>• “Yes because she is <i>using data to make business decisions</i>”</li> <li>• “<i>yes she made a graph to figure out when she needs more staff</i>.”</li> <li>• “Yes, because she performed an <i>analysis</i> and drew a conclusion, then made changes based on it.”</li> </ul> |

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- “Yes, because the *owner is doing math to figure out how many customers she has each day* and she is doing this in a very advanced way.”
  - “Yes, this demonstrates Computational Thinking *because creating a histogram and keeping track of information* requires problem-solving skills.”
  - “He is only making an observation and *not processing the information*”
  - “He's observing, but he isn't coming to any conclusions or *using the information* in any useful way.”
  - “No, he is only observing and *not actually processing any information*”
  - “Francis doesn't have to go line by line - he can *deduce which parts of the code could be giving the robot trouble and start from those sections of his code*”
  - “Following a recipe is CT at its core, and *she is changing it to include new ideas* important to her.”
  - “Grace is *assessing* her bread similarly to how Olivia was *assessing* her website, therefore she is also using computational thinking”
  - “Like the previous example, Grace is testing her recipe and editing accordingly, following a computational *approach of taking in feedback, processing what such feedback means, and changing necessary means as a result.*”
  - “She read a recipe and *decided to change it up to further expand on it*”
  - “She *understands her failures and looks for ways each time to improve the recipe*”
  - “*She uses her intuition and evidence from previous recipes to see what works and what doesn't.*”
  - “*tweaking numbers according to results* is like the process of machine learning”
  - “with each trial, she is *deducing what went good or bad*, and using that past knowledge to make the bread better”
  - “Yes because she followed step by step inductions and *made changes through recognizing what was working and what was not.*”
  - “Yes because she is demonstrating thinking *based on past performances of the recipe to make a better one*”
  - “Yes, because Grace is *tweaking the recipe which means she is adjusting the formula just enough each time and experimenting how this affects her bread.*”
  - “Hannah is creating *lists in order to compare information, which allows her to calculate the best possible outcome*, which I would consider computational thinking”
  - “Hannah's situation demonstrates Computational Thinking because she is breaking down a problem into *simpler pieces to help with her solution of deciding whether or not to attend*
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*graduate school.*”

- “Her several attributes have been *split up into a list to help her easily decide on the pros and cons*”
  - “She is *organizing the different factors in a way that makes it easier for her to make a decision*”
  - “She is *thinking hard about the positive and negatives of different options*”
  - “She is trying to *analyze* the situation by using logic and evidence.”
  - “She's *making a list to make a decision.*”
  - “*Yes as it breaks down each separate part that will go into her overall decision.*”
  - “Yes she is separating the idea into *parts and recognizing important factors of each part. Taking out the valued information.*”
  - “Yes, because *she has a strategy to come to the decision.*”
  - “Yes, because *she's making a logical decision based on the information* available to her.”
  - “Yes, because they are *sorting the factors based on patterns* of how they connect to their life.”
  - “Yes, Hannah is *making decisions by weighing the factors that impact her decision*. So this means that she is having to do advanced thinking about her decisions.”
  - “Lily is *tracking the pattern in her assignments in order to determine* when she should do her work, which is computational thinking”
  - “She is *keeping this information in a systematic manor* to keep herself on pace with her assignments.”
  - “She *isn't really processing the information*, just taking down notes”
  - “This *doesn't require much thought processing*. She just needs to know when the assignment is due and does not need to do any further thinking”
  - “No, because she merely observed, and *did not make an decision.*”
  - “She *does not have to deeply process the words* spoken in the interviews to write up the transcription”
  - “*She is not creating patterns, recognizing important information, or working with an algorithm. She is just following basic steps to complete a project.*”
  - “She is only listening and writing down what she hears, which *doesn't require her to process the information*”
  - “he's *quantifying results*, which is the first step to computing something, but he doesn't do anything after that with the numbers”
  - “Matt is *looking for patterns in his cooking to assess if he needs to make adjustments based on his personal enjoyment* of the food, which is computational thinking”
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- “No, because he is just noting down his experience but not really doing anything about the recipe.”
  - “Yes - Matt is collecting data to influence future pasta decisions. Data collection is computational.”
  - “Yes, because despite taste being a subjective measure, he is still using data to *analyze* his cooking, making his actions in the end logical.”
  - “*assessed* information broken into parts.”
  - “Olivia is *assessing* her company website and forming solutions based on her feedback, which is computational thinking”
  - “She is *changing and improving her website over time by taking into account feedback* and figuring out how she can add it to her website”
  - “She is writing programs which *requires understanding the feedback given on her and being able to implement it.*”
  - “Yes because *she is systematically making a business decision* via writing up a report of friends and family”
  - “Yes, because Olivia had to *weigh how much the feedback means to her and apply that information to make a decision* on how to design a good website to attract customers.”
  - “Yes, because *she drew on her resources to continue improving* the website.”
  - “*yes, she is taking advice, thinking about it, figuring out how she can implement it, and implements it*”
  - “No, the plumber is fixing the pipe by *analyzing* where the hole is. I don't think this is computational because computational sounds more like math.”
  - “because they are collecting data and *analyzing* the data”
  - “Making quantitative observations of plants and *assessing* them.”
  - “No, they are *merely observing, not making decisions.*”
  - “The Preschoolers are *assessing* information from a plant to notice any patterns in growth changes, which is computational thinking”
  - “They are *assessing* how much growth there is.”
  - “They can *use their data to create a mathematical model* of the plants growth.”
  - “They probably don't understand fully what any of the measurements mean. They are *just making observations*”
  - “Yes because she is getting data on the plants high and *using that data*”
  - “Yes this demonstrates Computational Thinking because it shows how the students are using
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|------------------------|-------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        |                                                                                                                         | <p>computational skills <i>to compare and evaluate the growth</i> of the plant.”</p> <ul style="list-style-type: none"> <li>• “Yes, because the preschoolers are writing down data about their plants and <i>analyzing</i> the changes of the growth of their plant.”</li> <li>• “Yes, because they're <i>analyzing</i> in a strategic manner.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Assigning Value</b> | Anytime the participant mentions assigning a value to qualitative information or when “rating” is explicitly mentioned. | <ul style="list-style-type: none"> <li>• “I feel like she <i>is computing scores for each one</i>”</li> <li>• “listing pros and cons isn't computational thinking because it's qualitative rather than quantitative. if she were to <i>assign a numeric value</i> to each pro and con and add them up for each option, then that would be computational thinking.”</li> <li>• “could be <i>subjective ratings</i>”</li> <li>• “Following a recipe is CT and <i>rating dishes</i> is extracting important information.”</li> <li>• “he is not really doing heavy thinking, and there isnt much information about what hes noting. if he was writing in-depth 5 paragraph essays on the tastes of the dish, then yes, but if <i>hes just doing a 5 star system</i> then its not.”</li> <li>• “He is <i>rating</i> each new recipe.”</li> <li>• “He is <i>rating</i> the dishes”</li> <li>• “he's <i>quantifying results</i>, which is the first step to computing something, but he doesn't do anything after that with the numbers”</li> <li>• “She is using feedback to <i>create scores</i> for each possibility”</li> <li>• “it's very simple computing, “which plant is the tallest”, but it still involves math because they're <i>comparing numeric values</i>”</li> <li>• “separating and <i>giving weight to different things</i> in order to compare them is computational thinking”</li> <li>• “Yes! <i>Weighing options</i> is definitely computational, as it involves a series of questions that could yield positive or negative outcomes. Similarly, computers function on a binary system of 0s and 1s, or “yes”es and “no”s.”</li> <li>• “Cole is <i>framing his daily walk in a mathematical sense</i>. He is using numbers to explain his timeline.”</li> </ul> |
| <b>Coding</b>          | Anytime the participant mentions “code”, “coding”, “a                                                                   | <ul style="list-style-type: none"> <li>• “She is modifying the website, like one would modify a <i>program</i>. It requires thinking to implement their suggestions.”</li> <li>• “She is writing <i>programs</i> which requires understanding the feedback given on her and being able to implement it.”</li> <li>• “Because they are dividing the tasks like a <i>program</i> would.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

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computer  
program”, or  
“programming  
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- “I’m not too sure about this answer. This is closer to computational thinking than Cole’s situation since Rich and his friends are decomposing the problem. However, they are not being as efficient about *coding* together as they could be - there is a lot of overlap between the four sub-programs that they aren’t taking the time to go over.”
  - “In order to *program* anything involving math, you have to do some computational thinking.”
  - “In this situation, a problem is expressed and *then solved in a way that a computer could also execute.*”
  - “Not only does this situation deal with actual math calculations, but Rich and his friends needed to delegate the work and add all of their *programs* together”
  - “*Programming* requires you think computationally how the program will run and then figure out how the different parts fit together”
  - “Rich and his friends are working on a computer *program* and therefore thinking about computation”
  - “The situation with Rich represents Computational Thinking because the end result is to create a computer *program* and by distributing different tasks of adding, subtracting, multiplying, and dividing it shows that it involves the problem-solving process.”
  - “there are too many variables, especially when combining the two *codes*. there is a very real possibility that the codes may not work together well if at all. It is unreliable it would be better to work together on the same *code*. It would be more efficient.”
  - “They are quite literally making a *program* in which the computer will solve different mathematical operations.”
  - “They are smartly splitting up the different parts they have to work on and write computer *programs*”
  - “they need to think of a way of how to get a computer to do the various arithmetic things, make it so the computer can understand it (“translate” it into *code* or however computers work), troubleshoot any problems that happen, and put them together and then troubleshoot any problems that happen when they’re put together.”
  - “They’re splitting up the work and working on a specific piece of the calculator computer *program.*”
  - “Yes, because they are having to format the information in a patterned way which *even a computer can run through.*”
  - “Yes, because they are writing a computer *program* that requires math and some form of advanced thinking”
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|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            |                                                                                                                                                       | <ul style="list-style-type: none"> <li>• “The plumber is using logic similarly to Francis with his <i>code</i>, and also demonstrates computational thinking in order to solve a problem”</li> <li>• “checking <i>code</i> is definitely thinking like a computer”</li> <li>• “Francis doesn't have to go line by line - he can deduce which parts of the <i>code</i> could be giving the robot trouble and start from those sections of his code”</li> <li>• “Francis is assessing his <i>code</i> for any errors, using logic. This is computational thinking”</li> <li>• “Francis is thinking deeply about his <i>code</i>”</li> <li>• “He is debugging his <i>code</i> methodically.”</li> <li>• “He is fixing his <i>code</i> and checking for bugs.”</li> <li>• “I think so, because he has to check the <i>code</i> and make the proper adjustment to it? unless the mistake is something simple like a missing semi colon, which in that case no”</li> <li>• “It involves <i>programming</i>”</li> <li>• “just checking over <i>code</i> doesnt seem computaitonal”</li> <li>• “No, because he is trying to debug his <i>code</i> by going line by line to find errors in his code. He doesn't seem to be solving the problem other than debugging.”</li> <li>• “This definitely indicates Computational Thinking because developing <i>codes</i> and algorithms requires proper calculations, therefore involving proper computations.”</li> <li>• “Yes as he has broken down the problem to each line of <i>code</i> and is taking steps to sort through it.”</li> </ul> |
| Comparison | When the participant mentions examining two or more things (i.e. data, outcomes, etc.) in contrast or mentions weighing different options or factors, | <ul style="list-style-type: none"> <li>• “By making the list and <i>comparing</i> the options she is thinking very logically and the solution will be presented when all the activates on those lists are compared.”</li> <li>• “By visualizing the factors, she is trying to solve the problem of <i>whether or not</i> to go to graduate school.”</li> <li>• “Hannah is breaking a tough decision down into smaller parts by listing <i>pros and cons</i>, benefits and drawbacks to attending graduate school.”</li> <li>• “Hannah is creating lists in order to <i>compare</i> information, which allows her to calculate the best possible outcome, which I would consider computational thinking”</li> <li>• “<i>Hannah is thinking critically about her options</i>”</li> <li>• “listing <i>pros and cons</i> isn't computational thinking because it's qualitative rather than quantitative. if she were to assign a numeric value to each pro and con and add them up for each option, then that would be computational thinking.”</li> <li>• “separating and giving weight to different things in order to <i>compare</i> them is computational</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                               |

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weighing pros  
and cons, or  
explicitly  
mentions the  
word  
“comparison”.

thinking”

- “*She is organizing the different factors in a way that makes it easier for her to make a decision*”
  - “She is thinking hard about the *positive and negatives* of different options”
  - “She is *weighing pros and cons*. Yes”
  - “She's taking her thoughts and using solutions and *comparisons* to solve”
  - “This is *comparing* and weighing options, like a computer would compare things.”
  - “Yes Hannah is using logic create a list of different ideas to try and solve the problem of *whether or not* to attend graduate school”
  - “Yes! Weighing options is definitely computational, as it involves a series of questions that could yield *positive or negative outcomes*. Similarly, computers function on a binary system of 0s and 1s, or “yes”es and “no”s.”
  - “Yes, Hannah is making decisions by *weighing the factors* that impact her decision. So this means that she is having to do advanced thinking about her decisions.”
  - “with each trial, she is deducing *what went good or bad*, and using that past knowledge to make the bread better”
  - “Yes, because Grace is tweaking the recipe which means she is *adjusting the formula just enough each time and experimenting how this affects her bread*.”
  - “Yes, because Olivia had to *weigh how much the feedback means to her* and apply that information to make a decision on how to design a good website to attract customers.”
  - “it's very simple computing, “which plant is the tallest”, but it still involves math because they're *comparing* numeric values”
  - “They are *comparing* notes and recording data.”
  - “They are just making observations and *comparing*, not really doing any deep thinking”
  - “They are taking numerous measures of their plant as it grows and *comparing* it to the plants of others.”
  - “This is a systematic collection of data and *comparison* of data at the end which could probably be executed by a computer.”
  - “Yes because they were trying to recognize a pattern in the planets growth *compared* to other students planets.”
  - “Yes this demonstrates Computational Thinking because it shows how the students are using computational skills to *compare* and evaluate the growth of the plant.”
  - “Yes! This is definitely computational, since the preschoolers are tracking and *comparing* data over a series of time.”
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|------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                  | <ul style="list-style-type: none"> <li>• “they need to think of a way of how to get a computer to do the various arithmetic things, make it so the computer can understand it ("translate" it into code or however computers work), <i>troubleshoot any problems that happen, and put them together and then troubleshoot any problems that happen when theyre put together.</i>”</li> <li>• “I believe <i>making pro and con</i> lists is an example of Computational Thinking because it is logical problem-solving.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <p><b>Computation</b></p> <p>When the participant mentions the action of calculating or computing something or explicitly mentioning the word “computation”.</p> | <ul style="list-style-type: none"> <li>• “Absolutely! The coffee shop owner is quite literally <i>computing</i> the average amount of customers per day to help her understand how to better support her business.”</li> <li>• “<i>calculating</i> customers per day”</li> <li>• “graphing numbers of customers is definitely <i>computing</i> things”</li> <li>• “This requires <i>calculations</i> and data visualization.”</li> <li>• “Cole is just observing things, he's not <i>calculating</i> or computing anything.”</li> <li>• “Checking code line by line forces Francis to <i>compute</i> the robot's actions.”</li> <li>• “not <i>computing</i>”</li> <li>• “This definitely indicates Computational Thinking because developing codes and algorithms requires proper calculations, therefore involving proper <i>computations</i>.”</li> <li>• “Hannah is creating lists in order to compare information, which allows her to <i>calculate</i> the best possible outcome, which I would consider computational thinking”</li> <li>• “I feel like she is <i>computing</i> scores for each one”</li> <li>• “Not <i>computing</i> anything”</li> <li>• “not <i>computing</i>”</li> <li>• “Not necessarily - Lily isn't <i>computing</i> anything but rather leaving herself a simple reminder. However, the act of planning around these reminders would be computational.”</li> <li>• “Luisa was simply typing what she heard, she did not need to <i>compute</i> anything from the conversations, such as hidden meaning or tone differences in the interview”</li> <li>• “not <i>computing</i> anything”</li> <li>• “Not necessarily -- I'm sure there is a <i>computation</i> on the neurological level, but Luisa isn't consciously computing anything.”</li> <li>• “the other parts of her project may have involved <i>computing</i> things, but I have not been given that information. the one part i do know about, which is that she transcribed interviews, doesn't involve math”</li> <li>• “He is following the recipe so he would be thinking and doing those steps <i>computationally</i>.”</li> </ul> |

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|----------|----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |                                                                                                                      | <ul style="list-style-type: none"> <li>• “he's quantifying results, which is the first step to <i>computing</i> something, but he doesn't do anything after that with the numbers”</li> <li>• “stating how much he likes it isnt thinking <i>computationally</i>”</li> <li>• “Yes - Matt is collecting data to influence future pasta decisions. Data collection is <i>computational</i>.”</li> <li>• “not <i>computing</i> anything”</li> <li>• “Yes - Olivia is taking in feedback and editing accordingly, which requires a degree of <i>computation</i>.”</li> <li>• “He is <i>calculating</i> where the hole might be at, and tries to find it.”</li> <li>• “not <i>computing</i>”</li> <li>• “Yes - by scanning the pipe, the plumber is taking a process of elimination approach, which is technically <i>computation</i>.”</li> <li>• “Although they are given instructions, they are still <i>computing</i> and observing the plant growth.”</li> <li>• “<i>computing</i> height”</li> <li>• “it's very simple <i>computing</i>, "which plant is the tallest", but it still involves math because they're comparing numeric values”</li> <li>• “Yes this demonstrates Computational Thinking because it shows how the students are using <i>computational</i> skills to compare and evaluate the growth of the plant.”</li> <li>• “I still dont understand, but I feel like this is more along the lines of <i>computing</i>”</li> <li>• “Rich and his friends are working on a computer program and therefore thinking about <i>computation</i>”</li> <li>• “The team is <i>computing</i> the most efficient way to finish the process, so yes.”</li> </ul> |
| Computer | Anytime the participant references a computer or something that a computer could do or execute such as a model, data | <ul style="list-style-type: none"> <li>• “She used a mathematical <i>model</i> to solve her problem.”</li> <li>• “There is a problem expressed and the proposed solution is run in a <i>computer</i> with data.”</li> <li>• “This requires calculations and <i>data visualization</i>.”</li> <li>• “checking code is definitely thinking like a <i>computer</i>”</li> <li>• “Plan of action that even a <i>computer</i> could do”</li> <li>• “This line by line solution is a systematic approach that a <i>computer</i> could likely run.”</li> <li>• “This is a solution to a problem that a <i>computer</i> program could run in a similar manner.”</li> <li>• “tweaking numbers according to results is like the process of <i>machine learning</i>”</li> <li>• “Hannah is thinking like a <i>computer scientist</i>”</li> <li>• “There is a method for finding a solution in this situation but it involves personal experience and</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

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|                                                                         | <p>visualization, or machine learning.</p> <p>opinions for Hannah that a <i>computer</i> may not be able to generate.”</p> <ul style="list-style-type: none"> <li>• “This is comparing and weighing options, like a <i>computer</i> would compare things.”</li> <li>• “Yes! Weighing options is definitely computational, as it involves a series of questions that could yield positive or negative outcomes. Similarly, <i>computers</i> function on a binary system of 0s and 1s, or "yes"es and "no"s.”</li> <li>• “This method involves human considerations that a <i>computer</i> might not duplicate.”</li> <li>• “She manually did something that a <i>computer</i> could do. She is organizing the data.”</li> <li>• “This is a solution to a problem that a <i>computer</i> could execute.”</li> <li>• “No, because its not something a <i>computer</i> could do.”</li> <li>• “This problem-solving method involves human opinion and subjective criteria that a <i>computer</i> would not be able to provide.”</li> <li>• “Reviewing the pipe section by section is a systematic approach that a <i>computer</i> could hypothetically run.”</li> <li>• “They can use their data to create a mathematical <i>model</i> of the plants growth.”</li> <li>• “This is a systematic collection of data and comparison of data at the end which could probably be executed by a <i>computer</i>.”</li> <li>• “In this situation, a problem is expressed and then solved in a way that a <i>computer</i> could also execute.”</li> <li>• “They are quite literally making a program in which the <i>computer</i> will solve different mathematical operations.”</li> <li>• “they are trying to have a <i>computer</i> solve different problems for them”</li> <li>• “they need to think of a way of how to get a <i>computer</i> to do the various arithmetic things, make it so the computer can understand it ("translate" it into code or however computers work), troubleshoot any problems that happen, and put them together and then troubleshoot any problems that happen when theyre put together.”</li> <li>• “Yes, because they are having to format the information in a patterned way which even a <i>computer</i> can run through.”</li> </ul> |
| <p><b>Data</b></p> <p>When the word “data” is explicitly mentioned.</p> | <ul style="list-style-type: none"> <li>• “because she is collecting <i>data</i> and analyzing the data logically”</li> <li>• “plan of action and quantitative <i>data</i>”</li> <li>• “She analyzed her <i>data</i> in order to come up with her next decision”</li> <li>• “She is able to analyze the <i>data</i> to make a logical decision”</li> <li>• “She is analyzing <i>data</i> and uses that data in a way to solve a problem or improve a system. It</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

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requires more thought process and creativity”

- “she takes down *data*, thinks about it, and makes a decision and action based on the data”
- “She took in very useful *data* from her customers and improved her work schedule in response”
- “The coffee shop owner is thinking computationally about the *data*”
- “There is a problem expressed and the proposed solution is run in a computer with *data*.”
- “This requires calculations and *data* visualization.”
- “Yes because she is using *data* to make business decisions”
- “Yes, because she used observation to gather *data* and made a logical decision based on that data.”
- “While the situation involves *data*, Cole is not seen to do any thinking about such data.”
- “No because he is not using *data*”
- “no because she is not making *data* or doing complex though”
- “shes just transferring *data* into another format”
- “No because this is more qualitative then quantitative *data*”
- “She manually did something that a computer could do. She is organizing the *data*.”
- “Yes - Matt is collecting *data* to influence future pasta decisions. Data collection is computational.”
- “Yes because he is getting *data* on the food he likes which as to do with numbers”
- “No because there is no numbers of *data*”
- “because they are collecting *data* and analyzing the data”
- “By doing the same actions over and over while recoding the *data* it shows computational thinking regardless of the results gotten.”
- “They are comparing notes and recording *data*.”
- “They can use their *data* to create a mathematical model of the plants growth.”
- “This is a systematic collection of *data* and comparison of data at the end which could probably be executed by a computer.”
- “Yes because she is getting *data* on the plants high and using that data”
- “Yes! This is definitely computational, since the preschoolers are tracking and comparing *data* over a series of time.”
- “Yes, because the preschoolers are writing down *data* about their plants and analyzing the changes of the growth of their plant.”

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**Debugging**

Mention of the

- “*Checking code line by line* forces Francis to compute the robot's actions.”
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process of  
detecting,  
locating, and  
fixing  
problems or  
finding errors,  
by testing or  
checking,  
going line by  
line or section  
by section,  
assessing code.

- “Francis doesn't have to *go line by line* - he can deduce which parts of the code could be giving the robot trouble and start from those sections of his code”
  - “Francis is *assessing his code for any errors*, using logic. This is computational thinking”
  - “*Going line by line* isn't really using your logic to figure out where the error possibly might be and narrow down how much code you have to check”
  - “he *finds an error*, and does a systematic process to find and correct the error”
  - “He is *debugging* his code methodically.”
  - “He is *fixing his code* and checking for bugs.”
  - “He is taking his robot apart and *looking continuously for patterns that would indicate why it is not working*.”
  - “He systematically *checks one thing at a time until he finds the error* which he will then be able to fix”
  - “He would probably have an easier time *debugging* if he used a tool rather than going line by line”
  - “I think so, because he has to *check the code and make the proper adjustment to it?* unless the mistake is something simple like a missing semi colon, which in that case no”
  - “No, because he is trying to *debug* his code by going line by line to find errors in his code. He doesn't seem to be solving the problem other than debugging.”
  - “Systematic approach *going line by line until an error is found* and problem is solved”
  - “Yes, because he's *testing all the different areas where there could be errors*.”
  - “She is essentially “*debugging*” the recipe.”
  - “By *checking section by section* he is repeating the same job over and over until it is complete.”
  - “*Going section by section probably isn't the most effective way to find a hole* - the plumber could just flush water down the pipe and see where it's leaking”
  - “*He is calculating where the hole might be at, and tries to find it*.”
  - “He is *debugging* the pipe.”
  - “*He is looking at the separate parts of the pipe to find the error*.”
  - “*He is trying to understand where the problem is*.”
  - “*he knows there is a problem and enacted a systematic process to find where the problem is and fix it*”
  - “He will be able to confirm that everything else is working up until *he finds the issue*”
  - “He works in part to find his solution. *He is looking for something to stand out in each section that would indicate the need for a certain solution*.”
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|                      |                                                                                                                                                     | <ul style="list-style-type: none"> <li>• “He’s going through a process of finding the broken pipe.”</li> <li>• “Reviewing the pipe section by section is a systematic approach that a computer could hypothetically run.”</li> <li>• “Using a system to inspect the pipe instead of randomly searching for the root of the problem”</li> <li>• “Yes he has steps by examining each section until the problem is found.”</li> <li>• “Yes this demonstrates Computational Thinking because inspecting the pipe might include being able to test out, tweak and identify the problem in order to develop a solution.”</li> <li>• “Yes, because he was testing the different parts of the pipe.”</li> <li>• “they need to think of a way of how to get a computer to do the various arithmetic things, make it so the computer can understand it (“translate” it into code or however computers work), troubleshoot any problems that happen, and put them together and then troubleshoot any problems that happen when they’re put together.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Decomposition</b> | When the participant mentions breaking a problem down or thinking of a solution into simpler or smaller parts or mentions decomposition explicitly. | <ul style="list-style-type: none"> <li>• “She had a problem and broke up how to find a solution. She then took the important information and implemented it into her solution idea.”</li> <li>• “Yes because she is breaking the problem down, taking only the information she needs to find out how many customers come in on certain days.”</li> <li>• “Although he is recognizing patterns he did not go out of his way to look for these patterns they were presented naturally to him. He is also not trying to break apart the situation it is just what is happening. This is a schedule more than a thought process”</li> <li>• “Yes because it breaks down the steps Cole takes during his walk and shows patterns in what he sees everyday.”</li> <li>• “break it down”</li> <li>• “He is taking his robot apart and looking continuously for patterns that would indicate why it is not working.”</li> <li>• “Yes as he has broken down the problem to each line of code and is taking steps to sort through it.”</li> <li>• “Yes, because he’s testing all the different areas where there could be errors.”</li> <li>• “tries to fix a problem a little by breaking it down”</li> <li>• “Break down complex problem into simpler parts.”</li> <li>• “Hannah is breaking a tough decision down into smaller parts by listing pros and cons, benefits and drawbacks to attending graduate school.”</li> <li>• “Hannah’s situation demonstrates Computational Thinking because she is breaking down a</li> </ul> |

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*problem into simpler pieces* to help with her solution of deciding whether or not to attend graduate school.”

- “Her *several attributes have been split up into a list* to help her easily decide on the pros and cons”
  - “*separating and giving weight to different things* in order to compare them is computational thinking”
  - “she is *breaking down her situation* but not in a mathematical sense.”
  - “Yes as it *breaks down each separate part* that will go into her overall decision.”
  - “Yes she is *separating the idea into parts* and recognizing important factors of each part. Taking out the valued information.”
  - “She is creating an agenda and *breaking it down by day*.”
  - “This is *decomposition* and abstraction”
  - “*Way to brake down a problem*.”
  - “*Did not break down a problem*.”
  - “Luisa didn't solve the problem of transcribing the interviews *by breaking it down into smaller problems* she could solve easily.”
  - “This does not *demonstrate any of the steps of computational thinking*”
  - “It's just a cooking journal. *Not breaking down a problem*.”
  - “*assessed information broken into parts*.”
  - “She uses both *decomposition* and algorithms to create a plan for her to make her website”
  - “Yes because she is *working in steps or parts* to create a finalized, edited site.”
  - “*breaking down sections*”
  - “He *works in part* to find his solution. He is looking for something to stand out in each section that would indicate the need for a certain solution.”
  - “This is an example of *decomposition*”
  - “They are not trying to solve any issue even if they are *working in what seems like steps*.”
  - “Because they are *dividing the tasks* like a program would.”
  - “*Break it down into smaller parts*.”
  - “I'm not too sure about this answer. This is closer to computational thinking than Cole's situation since Rich and his friends are *decomposing* the problem. However, they are not being as efficient about coding together as they could be - there is a lot of overlap between the four sub-programs that they aren't taking the time to go over.”
  - “No because it talks about the whole plan rather *then breaking down* each friend writes their
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|------------|----------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            |                                                                | <p>program.”</p> <ul style="list-style-type: none"> <li>• “no because the <i>tasks are split up</i> and not done consecutively”</li> <li>• “Not only does this situation deal with actual math calculations, but Rich and his friends needed to <i>delegate the work</i> and add all of their programs together”</li> <li>• “The situation with Rich represents Computational Thinking because the end result is to create a computer program and by <i>distributing different tasks</i> of adding, subtracting, multiplying, and dividing it shows that it involves the problem-solving process.”</li> <li>• “They are recognizing the situation, <i>breaking it into parts and steps</i>, then solving based on each step to put it together at the end. It is an algorithm.”</li> <li>• “They are <i>separating tasks</i> and are using logic.”</li> <li>• “They are <i>smartly splitting up the different parts</i> they have to work on and write computer programs”</li> <li>• “They’re <i>splitting up the work</i> and working on a specific piece of the calculator computer program.”</li> <li>• “Yes because they are <i>assigning tasks to different people</i> which each person will have to work on, was a problem solving that they potentially used logic to decide if not random”</li> <li>• “yes <i>because they DIVIDED the work</i> by the number of people”</li> <li>• “Yes, because Rich is <i>decomposing</i> the problem to make it easier for everyone”</li> <li>• “Yes, Rich is thinking computationally by <i>dividing the labor</i> among his group.”</li> </ul> |
| Difficulty | Anything that mentions the difficulty or simplicity of a task. | <ul style="list-style-type: none"> <li>• “She is analyzing data and uses that data in a way to solve a problem or improve a system. It <i>requires more thought process and creativity</i>”</li> <li>• “Yes, because the owner is doing math to figure out how many customers she has each day and <i>she is doing this in a very advanced way.</i>”</li> <li>• “Francis is <i>thinking deeply</i> about his code”</li> <li>• “He would probably <i>have an easier time debugging</i> if he used a tool rather than going line by line”</li> <li>• “I think so, because he has to check the code and make the proper adjustment to it? unless the <i>mistake is something simple</i> like a missing semi colon, which in that case no”</li> <li>• “She is <i>actively trying to figure out</i> the best way to make bread.”</li> <li>• “She modifies the recipe according to her needs, she <i>puts extra effort in modification.</i>”</li> <li>• “She needs to <i>think deeply</i> about how the recipe could be improved and takes steps to make changes in order to improve it”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

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- “Break down complex problem into *simpler parts*.”
  - “Hannah is *breaking a tough decision down* into smaller parts by listing pros and cons, benefits and drawbacks to attending graduate school.”
  - “Hannah's situation demonstrates Computational Thinking because she is breaking down a problem into *simpler pieces* to help with her solution of deciding whether or not to attend graduate school.”
  - “She is organizing the different factors in a way that *makes it easier for her* to make a decision”
  - “She is *thinking hard* about the positive and negatives of different options”
  - “Yes, Hannah is making decisions by weighing the factors that impact her decision. So this means that she is *having to do advanced thinking* about her decisions.”
  - “Lily *isn't thinking very deeply* about her assignments”
  - “no because she is not making data or *doing complex though*”
  - “No because she *is simply copying dates into a planner*. It doesn't require any creativity or problem solving or meaningful thinking besides her decision to start the process.”
  - “Not necessarily - Lily isn't computing anything but rather *leaving herself a simple reminder*. However, the act of planning around these reminders would be computational.”
  - “She doesn't really performs critical thinking, *she just writes what she needs to do*.”
  - “This doesn't indicate Computational Thinking because Lily *is simply writing down* the day each assignment is due, therefore there is no pattern or algorithm used.”
  - “This *doesn't require much thought processing*. She just needs to know when the assignment is due and does not need to do any further thinking”
  - “although it is a rote task, putting text to word has some computational thinking even if its very basic level. it also *may be more difficult if someone had a bad mic or speaks in a way they dont typically hear*”
  - “I chose “No” because Luisa *is simply typing up transcriptions* by watching online interviews, this doesn't require Computational Thinking and using problem-solving techniques.”
  - “Luisa is completing a task that *doesn't require much thought*”
  - “Luisa is typing words, but *not necessarily thinking about them*”
  - “Luisa *was simply typing what she heard*, she did not need to compute anything from the conversations, such as hidden meaning or tone differences in the interview”
  - “No because this part of her project only requires copying words down and *is a simple task*”
  - “No, because *she merely observed*, and did not make an decision.”
  - “No, because *she wasn't using any math to do her work or very advanced thinking*. Transcribing
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can be done mindlessly.”

- “Not necessarily -- I'm sure there is a computation on the neurological level, but Luisa *isn't consciously computing anything*.”
  - “Not not computation thinking here *more just autopilot working*”
  - “She *didn't need to think about the process*, she just typed what she heard”
  - “She *does not have to deeply process the words* spoken in the interviews to write up the transcription”
  - “She is not creating patterns, recognizing important information, or working with an algorithm. *She is just following basic steps* to complete a project.”
  - “She is only listening and writing down what she hears, *which doesn't require her to process the information*”
  - “She *isn't thinking about what is being said*, just writing things down.”
  - “There *isn't much thinking involved when making a transcript* other than maybe trying to understand what the people are saying. Although, when that happens, it is very straight forward and there is a correct answer.”
  - “This *is simply converting something* from one form to another.”
  - “*Transcription is less thinking*, more regurgitation.”
  - “transcripts not computational thinking because *it is just restating info*”
  - “*He is just enjoying his food*.”
  - “*He is just noting down his own personal opinions without doing any deep thinking*”
  - “*he is not really doing heavy thinking*, and there isn't much information about what hes noting. if he was writing in-depth 5 paragraph essays on the tastes of the dish, then yes, but if hes just doing a 5 star system then its not.”
  - “Matt *isn't thinking deeply* about the pastas”
  - “no because *he is simply following* the instructions and is noting his opinion”
  - “no because *she is simply adhering* to what other people are suggesting her to do which doesn't require any problem solving or complicated thinking on her part.”
  - “She is writing programs *which requires understanding the feedback* given on her and being able to implement it.”
  - “He is just searching until he finds it *which does not require any logic or deep thought* processing”
  - “He *is not using deep thought* processes in order to find the pipe. He is just looking around and hoping he finds it”
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|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                      | <ul style="list-style-type: none"> <li>• “No because <i>he is simply looking for something</i> that he will easily be able to identify.”</li> <li>• “sort of? he's <i>doing a simple search algorithm</i> to find the hole”</li> <li>• “The plumber <i>is thinking deeply</i> about the pipe”</li> <li>• “<i>it's very simple computing</i>, "which plant is the tallest", but it still involves math because they're comparing numeric values”</li> <li>• “They are just making observations and comparing, <i>not really doing any deep thinking</i>”</li> <li>• “They probably don't understand fully what any of the measurements mean. They are <i>just making observations</i>”</li> <li>• “<i>To a lesser extent</i>, but drawing pictures likely requires computational thinking, especially from a young child?”</li> <li>• “They <i>are smartly splitting up</i> the different parts they have to work on and write computer programs”</li> <li>• “Yes because <i>it requires a higher level of thinking</i> and involves problem solving”</li> <li>• “Yes, because they are writing a computer program that requires math and <i>some form of advanced thinking</i>”</li> <li>• “Yes, because they observed the requirements and <i>found a way to make it easier.</i>”</li> <li>• “<i>just looking for a hole doesnt seem computaitonal</i>”</li> </ul> |
| <p><b>Documentation</b></p> <p>The mention of recording, taking notes, or documenting new or unique information. However, copying or transcription is not included in this code.</p> | <ul style="list-style-type: none"> <li>• “By <i>recording</i> work loads and fixing only that problem by getting a fixed improvement (1 person) it is thinking computationally.”</li> <li>• “Takes quantitative <i>notes</i> on what is occurring and reacts to problems with logical solution”</li> <li>• “Yes, this demonstrates Computational Thinking because creating a histogram and <i>keeping track of information</i> requires problem-solving skills.”</li> <li>• “Because he's seeing the same occurrences at the same time each day, meaning that he is <i>keeping track of the time</i> whenever he sees the golden retriever by the fountain or the man turning off the lights.”</li> <li>• “He thinks through his daily routine and takes <i>note</i> of timing”</li> <li>• “hes not really doing any thinking except for <i>noting</i> that some things happen at the same time every day”</li> <li>• “No because she is <i>simply copying dates into a planner</i>. It doesn't require any creativity or problem solving or meaningful thinking besides her decision to start the process.”</li> <li>• “not computational bc she is just <i>writing</i> due dates”</li> <li>• “She doesn't really performs critical thinking, she just <i>writes</i> what she needs to do.”</li> </ul>                                                             |

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- “She isn't really processing the information, just taking down *notes*”
  - “This doesn't indicate Computational Thinking because Lily is simply *writing* down the day each assignment is due, therefore there is no pattern or algorithm used.”
  - “Luisa is *documenting* results.”
  - “He is just *noting* down his own personal opinions without doing any deep thinking”
  - “he is not really doing heavy thinking, and there isnt much information about what hes *noting*. if he was writing in-depth 5 paragraph essays on the tastes of the dish, then yes, but if hes just doing a 5 star system then its not.”
  - “No, because he is just *noting* down his experience but not really doing anything about the recipe.”
  - “This doesn't involve Computational Thinking because Matt is just *writing* down the taste, therefore it doesn't involve a problem-solving methodology.”
  - “Using a recipe to cook and then *writing* about what he liked”
  - “Using systematic method to *keep track* of how dish tastes”
  - “Yes because she is systematically making a business decision via *writing* up a report of friends and family”
  - “if its one classroom plant then they should all have the same height *written* down”
  - “only *reporting* info, not computational”
  - “Taking down *notes* on how their plant is growing”
  - “The kids are just *recording* their observations, not trying to solve a problem”
  - “They are comparing *notes* and recording data.”
  - “They are *taking numerous measures* of their plant as it grows and comparing it to the plants of others.”
  - “To a lesser extent, but *drawing pictures* likely requires computational thinking, especially from a young child?”
  - “Yes! This is definitely computational, since the preschoolers are *tracking* and comparing data over a series of time.”
  - “Yes, because the preschoolers are *writing* down data about their plants and analyzing the changes of the growth of their plant.”

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**Doesn't Understand**

This is when the survey respondent

- “*I think so, because he has to check the code and make the proper adjustment to it?* unless the mistake is something simple like a missing semi colon, which in that case no”
  - “*I'm not too sure about this* but I think that the planning part counts as computational thinking”
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|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            | does not understand something.                                                                                                                                                         | <ul style="list-style-type: none"> <li>• “<i>sort of?</i> he's doing a simple search algorithm to find the hole”</li> <li>• “<i>if its one classroom plant then they should all have the same height written down</i>”</li> <li>• “<i>I don't really understand what computational thinking is.</i>”</li> <li>• “<i>I still dont understand</i>, but I feel like this is more along the lines of computing”</li> <li>• “<i>I'm not too sure about this answer.</i> This is closer to computational thinking than Cole's situation since Rich and his friends are decomposing the problem. However, they are not being as efficient about coding together as they could be - there is a lot of overlap between the four sub-programs that they aren't taking the time to go over.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Efficiency | When the participant mentions efficiency or the use of a certain strategy which would increase or decrease efficiency, such as taking the relevant information, or optimize a process. | <ul style="list-style-type: none"> <li>• “She took in very useful data from her customers and <i>improved her work schedule</i> in response”</li> <li>• “Francis doesn't have to go line by line - <i>he can deduce which parts of the code could be giving the robot trouble</i> and start from those sections of his code”</li> <li>• “Going line by line isn't really using your logic to figure out where the error possibly might be and <i>narrow down how much code you have to check</i>”</li> <li>• “He would <i>probably have an easier time debugging</i> if he used a tool rather than going line by line”</li> <li>• “It is very <i>effective</i> and repeats the same job over and over until the problem is solved.”</li> <li>• “Grace <i>isn't trying to narrow down the ingredients that could bring the best results</i> - she is trying every single combination which isn't efficient at all.”</li> <li>• “She is actively trying to <i>figure out the best way to make bread.</i>”</li> <li>• “Hannah is creating lists in order to compare information, which allows her to <i>calculate the best possible outcome</i>, which I would consider computational thinking”</li> <li>• “Her several attributes have been split up <i>into a list to help her easily decide</i> on the pros and cons”</li> <li>• “She is organizing the different factors in a way that <i>makes it easier for her to make a decision</i>”</li> <li>• “No, she only did what she was supposed to be doing, didn't try to <i>optimize</i> it.”</li> <li>• “Yes, but only if he's making decisions as he goes to <i>optimize</i> the types of recipes he's choosing.”</li> <li>• “Olivia isn't trying to come up with the most <i>efficient</i> and abstracted way to improve her website - she is asking for feedback in a number of batches instead of trying to ask for it all at once in the most effective way possible.”</li> <li>• “Going section by section probably isn't the most <i>effective</i> way to find a hole - the plumber could just flush water down the pipe and see where it's leaking”</li> </ul> |

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|                   |                                                                                                       | <ul style="list-style-type: none"> <li>• “I’m not too sure about this answer. This is closer to computational thinking than Cole’s situation since Rich and his friends are decomposing the problem. However, they are not being as <i>efficient</i> about coding together as they could be - there is a lot of overlap between the four sub-programs that they aren’t taking the time to go over.”</li> <li>• “The team is computing the most <i>efficient</i> way to finish the process, so yes.”</li> <li>• “there are too many variables, especially when combining the two codes. there is a very real possibility that the codes may not work together well if at all. It is unreliable it would be better to work together on the same code. It would be more <i>efficient</i>.”</li> <li>• “<i>Yes because they work together to add up their skills</i>”</li> <li>• “Yes, because Rich is decomposing the problem <i>to make it easier for everyone</i>”</li> <li>• “Yes, because they observed the requirements and <i>found a way to make it easier</i>.”</li> </ul>                                                               |
| <b>Experiment</b> | When the participant mentions “experiment” explicitly or a part of the experimental process.          | <ul style="list-style-type: none"> <li>• “She is keeping her <i>experiment</i> under extreme control in order to observe the changes in one variable at a time.”</li> <li>• “Yes, because Grace is tweaking the recipe which means she is adjusting the formula just enough each time and <i>experimenting</i> how this affects her bread.”</li> <li>• “Yes, because she is progressing through the situation as if it was an <i>experiment</i>.”</li> <li>• “Yes, she’s <i>testing</i> things to improve.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Feedback</b>   | Participants mention receiving feedback, opinions, or suggestions that can be used to improve a task. | <ul style="list-style-type: none"> <li>• “Like the previous example, Grace is testing her recipe and editing accordingly, following a computational approach of taking in <i>feedback</i>, processing what such feedback means, and changing necessary means as a result.”</li> <li>• “Asked for <i>feedback</i> and is now using it to better edit her website”</li> <li>• “I don’t think so, since it was other people’s <i>feedback</i>.”</li> <li>• “maybe? editing something according to <i>feedback</i> could be done algorithmically”</li> <li>• “no because she is simply adhering to what other people are <i>suggesting</i> her to do which doesn’t require any problem solving or complicated thinking on her part.”</li> <li>• “Olivia is assessing her company website and forming solutions based on her <i>feedback</i>, which is computational thinking”</li> <li>• “Olivia isn’t trying to come up with the most efficient and abstracted way to improve her website - she is asking for <i>feedback</i> in a number of batches instead of trying to ask for it all at once in the most effective way possible.”</li> </ul> |

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|                 |                                                                                 | <ul style="list-style-type: none"> <li>• “Olivia retries each time getting <i>feedback</i> to make it better.”</li> <li>• “Olivia used problem solving to come up with a logical plan of how to design here website design, get <i>feedback</i>, and redesign based on that feed back”</li> <li>• “She is changing and improving her website over time by taking into account <i>feedback</i> and figuring out how she can add it to her website”</li> <li>• “She is gaining the <i>opinions</i> of her targeted customers to further improve her own website. This cycle will loop forever as she continues to receive feedback in order for her services to always best suit her audience.”</li> <li>• “She is making adjustments to her website based on <i>feedback</i> from different sources.”</li> <li>• “She is modifying the website, like one would modify a program. It requires thinking to implement their <i>suggestions</i>.”</li> <li>• “She is using <i>feedback</i> to create scores for each possibility”</li> <li>• “She is writing programs which requires understanding the <i>feedback</i> given on her and being able to implement it.”</li> <li>• “She was given <i>feedback</i>, she was given informations and instructions to follow.”</li> <li>• “she's upgrading her website based on <i>feedback</i>”</li> <li>• “took in info and made changes based on <i>feedback</i>”</li> <li>• “Yes - Olivia is taking in <i>feedback</i> and editing accordingly, which requires a degree of computation.”</li> <li>• “Yes because she is taking <i>feedback</i> from two sources and changing based on the responses in hopes of making a good website.”</li> <li>• “Yes, because Olivia had to weigh how much the <i>feedback</i> means to her and apply that information to make a decision on how to design a good website to attract customers.”</li> <li>• “Yes, because Olivia iterated her design based on <i>feedback</i>.”</li> <li>• “yes, she is <i>taking advice</i>, thinking about it, figuring out how she can implement it, and implements it”</li> </ul> |
| Following Steps | When mentioning steps that the participant or person in the question <i>has</i> | <ul style="list-style-type: none"> <li>• “She's <i>going through steps</i> to plan staffing”</li> <li>• “yes, <i>it is very step by step</i> and the events are always in the same order at the same time.”</li> <li>• “<i>Hes working through the lab step by step</i>”</li> <li>• “<i>This does not show any of the steps of computational thinking</i>”</li> <li>• “Yes as he has broken down the problem to each line of code and <i>is taking steps</i> to sort through it.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

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not created on  
their own:  
either  
following  
steps,  
instructions or  
a recipe.

- “*Following a recipe* is CT at its core, and she is changing it to include new ideas important to her.”
  - “*following the recipe* would be the example but when tweaking it with unknown amounts, it is not Computational Thinking.”
  - “*going through steps* of making her bread better”
  - “No, because *she is not following the recipe directly*, the unplanned changes are not computational.”
  - “She needs to think deeply about how the recipe could be improved and *takes steps* to make changes in order to improve it”
  - “Yes because she *followed step by step* inductions and made changes through recognizing what was working and what was not.”
  - “This does not *demonstrate any of the steps* of computational thinking”
  - “This doesn't indicate Computational Thinking because *Lily is simply writing down the day each assignment is due*, therefore there is no pattern or algorithm used.”
  - “*No, because their is no pattern to follow.*”
  - “She is not creating patterns, recognizing important information, or working with an algorithm. She is just *following basic steps* to complete a project.”
  - “*Following a recipe* is CT and rating dishes is extracting important information.”
  - “He is *following the recipe* so he would be thinking and doing those steps computationally.”
  - “*he's carrying out steps of cooking pasta*”
  - “no because he is simply *following the instructions* and is noting his opinion”
  - “*Using a recipe to cook* and then writing about what he liked”
  - “Yes because he is *following the recipe* step by step to solve the problem.”
  - “As far as *straight forward steps* go, it is a very linier plan produce-&gt; check-&gt; improve-&gt; repeat.”
  - “*she follows steps* to go to success in consecutives order”
  - “She was given feedback, *she was given informations and instructions to follow.*”
  - “sort of? *he's doing a simple search algorithm* to find the hole”
  - “Yes *he has steps* by examining each section until the problem is found.”
  - “Although *they are given instructions*, they are still computing and observing the plant growth.”
  - “They *followed a very systematic procedure* to notice the changes in their plants”
  - “This doesn't show *any of the primary steps* of computational thinking”
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| <p><b>Iteration</b></p> <p>Changing based on prior information to make better or implement a solution, but not necessarily to reach a “solution”.</p> | <ul style="list-style-type: none"> <li>• “She had a problem and broke up how to find a solution. She then took the important information and <i>implemented it into her solution idea.</i>”</li> <li>• “She is analyzing data and <i>uses that data in a way to solve a problem or improve a system.</i> It requires more thought process and creativity”</li> <li>• “she takes down data, thinks about it, and <i>makes a decision and action based on the data</i>”</li> <li>• “She took in very useful data from her customers and <i>improved her work schedule in response</i>”</li> <li>• “<i>using info collected to change her plan</i> for the coffee shop”</li> <li>• “Yes, because she performed an analysis and drew a conclusion, <i>then made changes based on it.</i>”</li> <li>• “<i>It is very effective and repeats the same job over and over until the problem is solved.</i>”</li> <li>• “Following a recipe is CT at its core, and <i>she is changing it to include new ideas</i> important to her.”</li> <li>• “going through steps of <i>making her bread better</i>”</li> <li>• “<i>Grace edits the equation of ingredients until she gets the desired outcome.</i>”</li> <li>• “Grace is demonstrating problem solving and creativity and is likely <i>only changing the numbers in the recipe by certain margins</i>”</li> <li>• “<i>if she does the tweaking in a structured and mathematically precise way</i>”</li> <li>• “Like the previous example, Grace is <i>testing her recipe and editing accordingly</i>, following a computational approach of taking in feedback, processing what such feedback means, and changing necessary means as a result.”</li> <li>• “She is keeping her experiment under extreme control in order to <i>observe the changes in one variable at a time.</i>”</li> <li>• “<i>she is trying to make it better so she is thinking through each change</i>”</li> <li>• “She <i>modifies the recipe according to her needs</i>, she puts extra effort in modification.”</li> <li>• “She needs to think deeply about how the recipe could be improved and <i>takes steps to make changes in order to improve it</i>”</li> <li>• “She <i>read a recipe and decided to change it up</i> to further expand on it”</li> <li>• “She understands her failures and <i>looks for ways each time to improve the recipe</i>”</li> <li>• “<i>tweaking numbers according to results is like the process of machine learning</i>”</li> <li>• “with each trial, she is deducing what went good or bad, and <i>using that past knowledge to make the bread better</i>”</li> <li>• “Yes because she followed step by step inductions and <i>made changes through recognizing what was working and what was not.</i>”</li> </ul> |
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- “Yes because she is demonstrating *thinking based on past performances of the recipe to make a better one*”
  - “Yes, because Grace is tweaking the recipe which means she is *adjusting the formula just enough each time* and experimenting how this affects her bread.”
  - “Yes, *she's testing things to improve.*”
  - “No because *he is not changing anything based on his opinions.* He will continue to try new recipes”
  - “As far as straight forward steps go, it is a very linear plan produce-&gt; check-&gt; improve-&gt; repeat.”
  - “Asked for feedback and is now *using it to better edit her website*”
  - “maybe? *editing something according to feedback* could be done algorithmically”
  - “*Olivia isn't trying to come up with the most efficient and abstracted way to improve her website* - she is asking for feedback in a number of batches instead of trying to ask for it all at once in the most effective way possible.”
  - “*Olivia retries each time getting feedback to make it better.*”
  - “Olivia used problem solving to come up with a logical plan of how to design her website design, get feedback, and *redesign based on that feedback*”
  - “She is *changing and improving her website over time* by taking into account feedback and figuring out how she can add it to her website”
  - “*She is gaining the opinions of her targeted customers to further improve her own website.* This cycle will loop forever as she continues to receive feedback in order for her services to always best suit her audience.”
  - “She is *making adjustments to her website* based on feedback from different sources.”
  - “She is *modifying the website*, like one would modify a program. It requires thinking to implement their suggestions.”
  - “She is *using feedback to create scores* for each possibility”
  - “She is *writing programs which requires understanding the feedback* given on her and being able to implement it.”
  - “*she's upgrading her website based on feedback*”
  - “*took in info and made changes based on feedback*”
  - “Yes - Olivia is *taking in feedback and editing accordingly*, which requires a degree of computation.”
  - “Yes because she is *taking feedback from two sources and changing based on the responses* in
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|-------------|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |                             | <p>hopes of making a good website.”</p> <ul style="list-style-type: none"> <li>• “Yes, because Olivia had to weigh how much the feedback means to her and <i>apply that information to make a decision on how to design a good website</i> to attract customers.”</li> <li>• “Yes, because Olivia <i>iterated</i> her design based on feedback.”</li> <li>• “Yes, because <i>she drew on her resources to continue improving the website.</i>”</li> <li>• “<i>yes, she is taking advice, thinking about it, figuring out how she can implement it, and implements it</i>”</li> <li>• “<i>By checking section by section he is repeating the same job over and over until it is complete.</i>”</li> <li>• “Yes this demonstrates Computational Thinking because <i>inspecting the pipe might include being able to test out, tweak and identify the problem</i> in order to develop a solution.”</li> <li>• “they need to think of a way of how to get a computer to do the various arithmetic things, make it so the computer can understand it (“translate” it into code or however computers work), <i>troubleshoot any problems that happen, and put them together and then troubleshoot any problems that happen when theyre put together.</i>”</li> </ul>                                                                                                                                                                            |
| <b>List</b> | Explicit mention of “list”. | <ul style="list-style-type: none"> <li>• “By making the <i>list</i> and comparing the options she is thinking very logically and the solution will be presented when all the activates on those lists are compared.”</li> <li>• “Hannah is breaking a tough decision down into smaller parts by <i>listing</i> pros and cons, benefits and drawbacks to attending graduate school.”</li> <li>• “Hannah is creating <i>lists</i> in order to compare information, which allows her to calculate the best possible outcome, which I would consider computational thinking”</li> <li>• “Her several attributes have been split up into a <i>list</i> to help her easily decide on the pros and cons”</li> <li>• “I believe making pro and con <i>lists</i> is an example of Computational Thinking because it is logical problem-solving.”</li> <li>• “<i>listing</i> pros and cons isn't computational thinking because it's qualitative rather than quantitative. if she were to assign a numeric value to each pro and con and add them up for each option, then that would be computational thinking.”</li> <li>• “Pros and cons <i>list</i> doesnt seem computational”</li> <li>• “She's making a <i>list</i> to make a decision.”</li> <li>• “Yes Hannah is using logic create a <i>list</i> of different ideas to try and solve the problem of whether or not to attend graduate school”</li> <li>• “Making a <i>list</i>”</li> </ul> |

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## Logic

When the participant explicitly mentions the use of logic or an intentional strategy in place.

- “because she is collecting data and analyzing the data *logically*”
  - “She is able to analyze the data to make a *logical* decision”
  - “Takes quantitative notes on what is occurring and reacts to problems with *logical* solution”
  - “Yes, because she used observation to gather data and made a *logical* decision based on that data.”
  - “because there is *logic* to this method in consecutive order”
  - “Francis is assessing his code for any errors, using *logic*. This is computational thinking”
  - “Going line by line isn't really using your *logic* to figure out where the error possibly might be and narrow down how much code you have to check”
  - “because she is using try and error not *logic*”
  - “She is using problem solving in a *logically* organized to figure out how to better the recipe”
  - “By making the list and comparing the options she is thinking very *logically* and the solution will be presented when all the activates on those lists are compared.”
  - “I believe making pro and con lists is an example of Computational Thinking because it is *logical* problem-solving.”
  - “She is trying to analyze the situation by using *logic* and evidence.”
  - “Yes because she is thinking *logically* and systematically about her choices”
  - “Yes Hannah is using *logic* create a list of different ideas to try and solve the problem of whether or not to attend graduate school”
  - “Yes, because *she has a strategy* to come to the decision.”
  - “Yes, because she's making a *logical* decision based on the information available to her.”
  - “Has a problem and using *logical* thinking to come up with a solutions”
  - “Yes, because she made a *logical* decision in order to help her achieve her goal.”
  - “It is very subjective thinking without solid *logic*”
  - “Yes, because despite taste being a subjective measure, he is still using data to analyze his cooking, making his actions in the end *logical*.”
  - “Olivia used problem solving to come up with a *logical* plan of how to design here website design, get feedback, and redesign based on that feed back”
  - “He is just searching until he finds it which does not require any *logic* or deep thought processing”
  - “The plumber is using *logic* similarly to Francis with his code, and also demonstrates computational thinking in order to solve a problem”
  - “yes because he comes orderly and *logically* in order so he can find the whole”
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|                                                                                                                                                                                 | <ul style="list-style-type: none"> <li>• “Yes, there is a clear <i>logic</i> to the plumber's decision and methodology.”</li> <li>• “They are separating tasks and are using <i>logic</i>.”</li> <li>• “This situation describes mathematical and <i>logical</i> thinking so therefore it represents Computational Thinking.”</li> <li>• “Yes because they are assigning tasks to different people which each person will have to work on, was a problem solving that they potentially used <i>logic</i> to decide if not random”</li> <li>• “Yes, because Rich made a <i>logical</i> decision based on the resources available to him.”</li> <li>• “Yes, because Francis <i>is using a methodological process</i> in order to solve problems.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <p><b>Math</b></p> <p>Anytime the participant uses mathematical terms as rational or when the participant references the use of mathematical methods to approach a problem.</p> | <ul style="list-style-type: none"> <li>• “Absolutely! The coffee shop owner is quite literally <i>computing the average amount of customers</i> per day to help her understand how to better support her business.”</li> <li>• “<i>calculating</i> customers per day”</li> <li>• “<i>graphing numbers</i> of customers is definitely computing things”</li> <li>• “She is using <i>numbers</i> to predict”</li> <li>• “She made a <i>graph</i> to see how many customers she gets on certain days”</li> <li>• “She used a <i>mathematical</i> model to solve her problem.”</li> <li>• “She's using <i>mathematical</i>-based solutions to solve her problem”</li> <li>• “This requires <i>calculations</i> and data visualization.”</li> <li>• “yes she made a <i>graph</i> to figure out when she needs more staff.”</li> <li>• “Yes, because the owner is doing <i>math</i> to figure out how many customers she has each day and she is doing this in a very advanced way.”</li> <li>• “Yes, this demonstrates Computational Thinking because creating a <i>histrogram</i> and keeping track of information requires problem-solving skills.”</li> <li>• “Cole is framing his daily walk in a <i>mathematical</i> sense. He is using numbers to explain his timeline.”</li> <li>• “This definitely indicates Computational Thinking because developing codes and algorithms requires proper <i>calculations</i>, therefore involving proper computations.”</li> <li>• “Grace edits the <i>equation</i> of ingredients until she gets the desired outcome.”</li> <li>• “Grace is demonstrating problem solving and creativity and is likely only changing the <i>numbers</i> in the recipe by certain margins”</li> <li>• “if she does the tweaking in a structured and <i>mathematically</i> precise way”</li> <li>• “tweaking <i>numbers</i> according to results is like the process of machine learning”</li> <li>• “Yes, because Grace is tweaking the recipe which means she is adjusting the <i>formula</i> just</li> </ul> |

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- enough each time and experimenting how this affects her bread.”
- “listing pros and cons isn't computational thinking because it's qualitative rather than quantitative. if she were to assign a *numeric* value to each pro and con and add them up for each option, then that would be computational thinking.”
  - “she is breaking down her situation but not in a *mathematical* sense.”
  - “doesn't involve *math*”
  - “No, because she wasn't using any *math* to do her work or very advanced thinking. Transcribing can be done mindlessly.”
  - “the other parts of her project may have involved computing things, but I have not been given that information. the one part i do know about, which is that she transcribed interviews, doesn't involve *math*”
  - “he's *quantifying* results, which is the first step to computing something, but he doesn't do anything after that with the *numbers*”
  - “Yes because he is getting data on the food he likes which as to do with *numbers*”
  - “He is *calculating* where the hole might be at, and tries to find it.”
  - “No because there is no *numbers* of data”
  - “No, the plumber is fixing the pipe by analyzing where the hole is. I don't think this is computational because computational sounds more like *math*.”
  - “it's very simple computing, "which plant is the tallest", but it still involves *math* because they're comparing numeric values”
  - “They are not doing *math*”
  - “They are taking numerous *measures* of their plant as it grows and comparing it to the plants of others.”
  - “They can use their data to create a *mathematical* model of the plants growth.”
  - “They probably don't understand fully what any of the *measurements* mean. They are just making observations”
  - “In order to program anything involving *math*, you have to do some computational thinking.”
  - “The situation with Rich represents Computational Thinking because the end result is to create a computer program and by distributing different tasks of adding, subtracting, multiplying, and dividing it shows that it involves the problem-solving process.”
  - “their situation could be represented by an *equation*.”
  - “They are quite literally making a program in which the computer will solve different *mathematical* operations.”
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|                                                                                                                                                                  | <ul style="list-style-type: none"> <li>• “they need to think of a way of how to get a computer to do the various <i>arithmetic</i> things, make it so the computer can understand it ("translate" it into code or however computers work), troubleshoot any problems that happen, and put them together and then troubleshoot any problems that happen when theyre put together.”</li> <li>• “This situation describes <i>mathematical</i> and logical thinking so therefore it represents Computational Thinking.”</li> <li>• “Yes because he is making stuff related to <i>math</i>”</li> <li>• “yes because they <i>DIVIDED</i> the work by the number of people”</li> <li>• “Yes, because they are writing a computer program that requires <i>math</i> and some form of advanced thinking”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <p><b>Observation</b></p> <p>Mentions of observing, viewing repetitions, paying attention to something, noticing, looking at something, or seeing something.</p> | <ul style="list-style-type: none"> <li>• “Yes, because she used <i>observation</i> to gather data and made a logical decision based on that data.”</li> <li>• “Because he's <i>seeing</i> the same occurrences at the same time each day, meaning that he is keeping track of the time whenever he sees the golden retriever by the fountain or the man turning off the lights.”</li> <li>• “Cole is just <i>observing</i> things, he's not calculating or computing anything.”</li> <li>• “Cole is <i>observing</i>, not thinking about what happens on his walk.”</li> <li>• “Cole pays attention to the details such as the time he <i>sees</i> these occurrences and observes that it's repetitive.”</li> <li>• “He has <i>noticed</i> the same two events along his morning walk that always occur in a specific order and time”</li> <li>• “He is only making an <i>observation</i> and not processing the information”</li> <li>• “He just is <i>observing</i> things, not thinking.”</li> <li>• “He's <i>observing</i>, but he isn't coming to any conclusions or using the information in any useful way.”</li> <li>• “It's just an <i>observation</i>.”</li> <li>• “Making <i>observation</i> and seeing patterns of things around him”</li> <li>• “No because he is simply <i>noticing</i> information going on around him.”</li> <li>• “No, because he is only <i>observing</i> things that happen around him at certain times”</li> <li>• “No, he is only <i>observing</i> and not actually processing any information”</li> <li>• “There is no problem-solving involved in this situation, it is only <i>observations</i> being made.”</li> <li>• “This doesn't count as computational thinking because Cole isn't solving a problem, he is only</li> </ul> |

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|                 |                                                       | <p><i>observing</i> that something occurs at x time”</p> <ul style="list-style-type: none"> <li>• “This is simply <i>observing</i>, not thinking.”</li> <li>• “She is keeping her experiment under extreme control in order to <i>observe</i> the changes in one variable at a time.”</li> <li>• “No, because she merely <i>observed</i>, and did not make an decision.”</li> <li>• “She "autonomously" watched these interviews and <i>observed</i> thoughts from others to create her own output.”</li> <li>• “He is <i>looking</i> at the separate parts of the pipe to find the error.”</li> <li>• “He is not using deep thought processes in order to find the pipe. He is just <i>looking</i> around and hoping he finds it”</li> <li>• “He is <i>observing</i> to identify the location of the problem.”</li> <li>• “No because he is simply <i>looking</i> for something that he will easily be able to identify.”</li> <li>• “Although they are given instructions, they are still computing and <i>observing</i> the plant growth.”</li> <li>• “Making quantitative <i>observations</i> of plants and assessing them.”</li> <li>• “No, they are merely <i>observing</i>, not making decisions.”</li> <li>• “<i>Taking down notes</i> on how their plant is growing”</li> <li>• “The kids are just recording their <i>observations</i>, not trying to solve a problem”</li> <li>• “They are just making <i>observations</i> and comparing, not really doing any deep thinking”</li> <li>• “They followed a very systematic procedure to <i>notice</i> the changes in their plants”</li> <li>• “They probably don't understand fully what any of the measurements mean. They are just making <i>observations</i>”</li> <li>• “you <i>see</i> progression”</li> <li>• “Yes, because they <i>observed</i> the requirements and found a way to make it easier.”</li> <li>• “<i>following their plant growing process</i>”</li> </ul> |
| <b>Order</b>    | Mentions the order of events or tasks in the example. | <ul style="list-style-type: none"> <li>• “because there is logic to this method in consecutive <i>order</i>”</li> <li>• “He is doing a planned task in planned <i>order</i>.”</li> <li>• “she follows steps to go to success in consecutives <i>order</i>”</li> <li>• “yes because he comes <i>orderly</i> and logically in order so he can find the whole”</li> <li>• “no because the tasks are split up and <i>not done consecutively</i>”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Organize</b> | Mention of a systematic, structured,                  | <ul style="list-style-type: none"> <li>• “because there is no <i>organizational</i> part to it”</li> <li>• “She manually did something that a computer could do. She is <i>organizing</i> the data.”</li> <li>• “Using <i>systematic method</i> to keep track of how dish tastes”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

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organized, or  
methodological  
approach.

- “he finds an error, and does a *systematic process* to find and correct the error”
  - “He is debugging his code *methodically*.”
  - “He *systematically checks* one thing at a time until he finds the error which he will then be able to fix”
  - “*Systematic approach* going line by line until an error is found and problem is solved”
  - “This line by line solution is a *systematic approach* that a computer could likely run.”
  - “if she does the tweaking in a *structured* and mathematically precise way”
  - “She is using problem solving in a logically *organized* to figure out how to better the recipe”
  - “*because she is putting things in categories*”
  - “*separating and giving weight to different things in order to compare* them is computational thinking”
  - “She is *organizing* the different factors in a way that makes it easier for her to make a decision”
  - “Yes, because they are *sorting the factors* based on patterns of how they connect to their life.”
  - “A *calendar that helps her figure out what is due* when so that she can complete assignments on time”
  - “because she is just *organizing* her thoughts”
  - “She is *keeping this information in a systematic manner* to keep herself on pace with her assignments.”
  - “This is just planning ahead and being *organized*.”
  - “*When she gets an assignment it goes in the corresponding day every time*.”
  - “he knows there is a problem and enacted a *systematic process* to find where the problem is and fix it”
  - “Reviewing the pipe section by section is a *systematic approach* that a computer could hypothetically run.”
  - “*Using a system to inspect the pipe* instead of randomly searching for the root of the problem”
  - “They followed a very *systematic procedure* to notice the changes in their plants”
  - “This is a *systematic collection* of data and comparison of data at the end which could probably be executed by a computer.”
  - “Yes, because they're analyzing in a *strategic manner*.”
  - “Not only does this situation deal with actual math calculations, but Rich and his friends *needed to delegate the work and add all of their programs together*”
  - “This situation was thought out in an *organized* fashion such that everything will be taken care of in an even and fair way.”
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|                            |                                                             | <ul style="list-style-type: none"> <li>• “Yes, because they are having to <i>format the information in a patterned</i> way which even a computer can run through.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Pattern Recognition</b> | Any mention of patterns, noticing a pattern, or repetition. | <ul style="list-style-type: none"> <li>• “The coffee shop owner <i>tracked patterns</i> and came up with a solution for a busy day of the week, demonstrating computational thinking”</li> <li>• “This, I believe, is <i>pattern recognition</i>”</li> <li>• “Although he is <i>recognizing patterns</i> he did not go out of his way to look for these patterns they were presented naturally to him. He is also not trying to break apart the situation it is just what is happening. This is a schedule more than a thought process”</li> <li>• “because he is <i>noticing the patterns</i>”</li> <li>• “Cole is experiencing <i>pattern recognition</i>”</li> <li>• “Cole pays attention to the details such as the time <i>he sees these occurrences and observes that it's repetitive.</i>”</li> <li>• “hes not really doing any thinking except for <i>noting that some things happen at the same time every day</i>”</li> <li>• “I selected "Yes" because I believe there was computation involved in this line of thinking. I would describe this as <i>noticing a recurring pattern</i>, or trend, which is both critical thinking as well as calculating time of occurrences.”</li> <li>• “Making observation and <i>seeing patterns</i> of things around him”</li> <li>• “While he is <i>observing a pattern</i> daily, there is no problem to be solved which is a part of computational thinking”</li> <li>• “Yes because it breaks down the steps Cole takes during his walk and <i>shows patterns in what he sees everyday.</i>”</li> <li>• “Yes, because it is a <i>very precise pattern.</i>”</li> <li>• “yes, it is very step by step and <i>the events are always in the same order at the same time.</i>”</li> <li>• “He is taking his robot apart and <i>looking continuously for patterns</i> that would indicate why it is not working.”</li> <li>• “Yes, because they are sorting the factors <i>based on patterns</i> of how they connect to their life.”</li> <li>• “Lily is <i>tracking the pattern</i> in her assignments in order to determine when she should do her work, which is computational thinking”</li> <li>• “This doesn't indicate Computational Thinking because Lily is simply writing down the day each assignment is due, therefore <i>there is no pattern</i> or algorithm used.”</li> <li>• “No, because <i>their is no pattern</i> to follow.”</li> </ul> |

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|                                                                                                                                        | <ul style="list-style-type: none"> <li>• “She is <i>not creating patterns</i>, recognizing important information, or working with an algorithm. She is just following basic steps to complete a project.”</li> <li>• “Matt is <i>looking for patterns</i> in his cooking to assess if he needs to make adjustments based on his personal enjoyment of the food, which is computational thinking”</li> <li>• “The Preschoolers are assessing information from a plant to <i>notice any patterns</i> in growth changes, which is computational thinking”</li> <li>• “Yes because they were trying to <i>recognize a pattern</i> in the planets growth compared to other students planets.”</li> <li>• “Yes, because they are having to <i>format the information in a patterned way</i> which even a computer can run through.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <p><b>Plan</b></p> <p>Mentioning a strategy or plan, or mentioning the use of a calendar or agenda for planning events or actions.</p> | <ul style="list-style-type: none"> <li>• “<i>plan</i> of action and quantitative data”</li> <li>• “She analysis the input to project an output <i>plan</i>.”</li> <li>• “She's going through steps to <i>plan</i> staffing”</li> <li>• “using info collected to change her <i>plan</i> for the coffee shop”</li> <li>• “<i>Plan</i> of action that even a computer could do”</li> <li>• “No, because she is not following the recipe directly, the <i>unplanned</i> changes are not computational.”</li> <li>• “Yes, because she has a <i>strategy</i> to come to the decision.”</li> <li>• “<i>A calendar that helps her figure out what is due when</i> so that she can complete assignments on time”</li> <li>• “I'm not too sure about this but I think that the <i>planning</i> part counts as computational thinking”</li> <li>• “Lily is tracking the pattern in her assignments <i>in order to determine when she should do her work</i>, which is computational thinking”</li> <li>• “No, she is mainly <i>planning</i> her schedule.”</li> <li>• “Not necessarily - Lily isn't computing anything but rather leaving herself a simple reminder. However, the act of <i>planning</i> around these reminders would be computational.”</li> <li>• “<i>plan</i> of action”</li> <li>• “She is creating an <i>agenda</i> and breaking it down by day.”</li> <li>• “She is only <i>planning</i>”</li> <li>• “She is <i>planning</i> ahead.”</li> <li>• “This doesn't require much thought processing. She just needs to <i>know when the assignment is due</i> and does not need to do any further thinking”</li> </ul> |

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|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                   | <ul style="list-style-type: none"> <li>• “This is just <i>planning</i> ahead and being organized.”</li> <li>• “Yes because she is <i>planning</i> out when assignments are do in order to take the steps to complete them.”</li> <li>• “No because Luisa already finished her project through typing every interview rather then come up with another <i>plan</i>.”</li> <li>• “He is doing a <i>planned task in planned order</i>.”</li> <li>• “As far as straight forward steps go, it is a very linier <i>plan</i> produce-&amp;gt; check-&amp;gt; improve-&amp;gt; repeat.”</li> <li>• “Olivia used problem solving to come up with a logical <i>plan</i> of how to design here website design, get feedback, and redesign based on that feed back”</li> <li>• “She uses both decomposition and algorithms to create a <i>plan</i> for her to make her website”</li> <li>• “There's no specific <i>plan</i> for it”</li> <li>• “very direct step by step <i>plan</i>”</li> <li>• “They have a set <i>plan</i>”</li> <li>• “No because it talks about the whole <i>plan</i> rather then breaking down each friend writes their program.”</li> <li>• “This situation was <i>thought out in an organized fashion</i> such that everything will be taken care of in an even and fair way.”</li> </ul>            |
| <b>Problem Solving</b><br><br>When the participant mentions any aspect of the problem solving process, including “solving”, “fixing”, “figuring out”, “problem solving”, “solve a | <ul style="list-style-type: none"> <li>• “Using a system to inspect the pipe instead of randomly <i>searching for the root of the problem</i>”</li> <li>• “there are too many variables, especially when <i>combining the two codes. there is a very real possibility that the codes may not work together well if at all</i>. It is unreliable it would be better to work together on the same code. It would be more efficient.”</li> <li>• “By recording work loads and <i>fixing</i> only that problem by getting a fixed improvement (1 person) it is thinking computationally.”</li> <li>• “She had a problem and broke up how to <i>find a solution</i>. She then took the important information and implemented it into her solution idea.”</li> <li>• “She is analyzing data and uses that data in a way to <i>solve a problem</i> or improve a system. It requires more thought process and creativity”</li> <li>• “She used a mathematical model to <i>solve her problem</i>.”</li> <li>• “She's using mathematical-based solutions to <i>solve her problem</i>”</li> <li>• “Takes quantitative notes on what is occurring and <i>reacts to problems with logical solution</i>”</li> <li>• “There is a <i>problem expressed and the proposed solution</i> is run in a computer with data.”</li> </ul> |

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problem”, or  
comments on  
any attempt to  
solve a  
problem.

- “yes she made a graph to *figure out* when she needs more staff.”
  - “Yes, this demonstrates Computational Thinking because creating a histogram and keeping track of information requires *problem-solving* skills.”
  - “He's not actively trying to *figure out any solutions to problems* he's having”
  - “I don't think it's *problem-solving* related.”
  - “There is no *problem-solving* involved in this situation, it is only observations being made.”
  - “This doesn't count as computational thinking because Cole isn't *solving a problem*, he is only observing that something occurs at x time”
  - “This is not a situation that demonstrates Computational Thinking because there is no *problem-solving* involved.”
  - “While he is observing a pattern daily, there is no *problem to be solved* which is a part of computational thinking”
  - “He systematically checks one thing at a time until he *finds the error which he will then be able to fix*”
  - “It is very effective and repeats the same job over and over until the *problem is solved*.”
  - “No, because he is trying to debug his code by going line by line to find errors in his code. He doesn't seem to be *solving the problem* other than debugging.”
  - “Systematic approach going line by line until an error is found and *problem is solved*”
  - “Yes as he has broken down the problem to each line of code and is taking steps to *sort through it*.”
  - “Yes, because Francis is using a methodological process in order to *solve problems*.”
  - “Grace is demonstrating *problem solving* and creativity and is likely only changing the numbers in the recipe by certain margins”
  - “She is using *problem solving* in a logically organized to figure out how to better the recipe”
  - “This is a *solution to a problem* that a computer program could run in a similar manner.”
  - “This situation demonstrates Computational Thinking because by using trial and error it shows that she's trying to create a *solution to the problem*.”
  - “tries to *fix a problem* a little by breaking it down”
  - “By making the list and comparing the options she is thinking very logically and the *solution* will be presented when all the activates on those lists are compared.”
  - “By visualizing the factors, she is trying to *solve the problem* of whether or not to go to graduate school.”
  - “Hannah's situation demonstrates Computational Thinking because she is *breaking down a*
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*problem into simpler pieces to help with her solution* of deciding whether or not to attend graduate school.”

- “I believe making pro and con lists is an example of Computational Thinking because it is logical *problem-solving*.”
  - “It's an interesting example of *problem solving* where Hannah must put a certain value for each of her interests and core priorities and must balance them out”
  - “She's taking her thoughts and *using solutions and comparisons to solve*”
  - “There is a method for *finding a solution* in this situation but it involves personal experience and opinions for Hannah that a computer may not be able to generate.”
  - “Yes Hannah is using logic create a list of different ideas to try and *solve the problem* of whether or not to attend graduate school”
  - “Has a *problem and using logical thinking to come up with a solutions*”
  - “No because she is simply copying dates into a planner. It doesn't require any creativity or *problem solving* or meaningful thinking besides her decision to start the process.”
  - “not trying to *figure anything out*”
  - “Yes, because she saw a *problem and identified a solution*.”
  - “I chose "No" because Luisa is simply typing up transcriptions by watching online interviews, this doesn't require Computational Thinking and using *problem-solving* techniques.”
  - “Luisa didn't *solve the problem* of transcribing the interviews by breaking it down into smaller problems she could solve easily.”
  - “No *problem-solving*”
  - “She doesn't seem like she's *solving any problems* out”
  - “This is a *solution to a problem* that a computer could execute.”
  - “There is no *problem being solved* in this situation.”
  - “This doesn't have to do with *problem-solving* at all”
  - “This doesn't involve Computational Thinking because Matt is just writing down the taste, therefore it doesn't involve a *problem-solving* methodology.”
  - “Yes because he is following the recipe step by step to *solve the problem*.”
  - “no because she is simply adhering to what other people are suggesting her to do which doesn't require any *problem solving* or complicated thinking on her part.”
  - “Olivia used *problem solving* to come up with a logical plan of how to design here website design, get feedback, and redesign based on that feed back”
  - “This *problem-solving* method involves human opinion and subjective criteria that a computer
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|                                       |                                                                        | <p>would not be able to provide.”</p> <ul style="list-style-type: none"> <li>• “This situation with Olivia demonstrates Computational Thinking because as Olivia is making her website she is most likely using algorithms or different <i>problem-solving</i> techniques to get to her end goal.”</li> <li>• “He is observing to <i>identify the location of the problem</i>.”</li> <li>• “he knows there is a problem and enacted a systematic process to <i>find where the problem is and fix it</i>”</li> <li>• “No, the plumber is <i>fixing</i> the pipe by analyzing where the hole is. I don't think this is computational because computational sounds more like math.”</li> <li>• “The plumber is using logic similarly to Francis with his code, and also demonstrates computational thinking in order to <i>solve a problem</i>”</li> <li>• “Yes this demonstrates Computational Thinking because inspecting the pipe might include being able to test out, tweak and <i>identify the problem in order to develop a solution</i>.”</li> <li>• “The kids are just recording their observations, not trying to <i>solve a problem</i>”</li> <li>• “They are not trying to <i>solve any issue</i> even if they are working in what seems like steps.”</li> <li>• “In this situation, a <i>problem is expressed and then solved</i> in a way that a computer could also execute.”</li> <li>• “The situation with Rich represents Computational Thinking because the end result is to create a computer program and by distributing different tasks of adding, subtracting, multiplying, and dividing it shows that it involves the <i>problem-solving</i> process.”</li> <li>• “They are recognizing the situation, breaking it into parts and steps, then <i>solving</i> based on each step to put it together at the end. It is an algorithm.”</li> <li>• “they are trying to have a computer <i>solve different problems</i> for them”</li> <li>• “They are <i>working out a problem</i>”</li> <li>• “Yes because they are assigning tasks to different people which each person will have to work on, was a <i>problem solving</i> that they potentially used logic to decide if not random”</li> </ul> |
| Qualitative or Quantitative Reasoning | Anytime a participant uses the language qualitative or quantitative or | <ul style="list-style-type: none"> <li>• “plan of action and <i>quantitative data</i>”</li> <li>• “She is <i>using numbers</i> to predict”</li> <li>• “Takes <i>quantitative</i> notes on what is occurring and reacts to problems with logical solution”</li> <li>• “She is using <i>qualitative</i>”</li> <li>• “listing pros and cons isn't computational thinking because it's <i>qualitative rather than quantitative</i>. if she were to assign a numeric value to each pro and con and add them up for each</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

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|                 | <p>references using qualitative or quantitative methods.</p>                                          | <p>option, then that would be computational thinking.”</p> <ul style="list-style-type: none"> <li>• “No because this is more <i>qualitative then quantitative</i> data”</li> <li>• “he’s <i>quantifying</i> results, which is the first step to computing something, but he doesn’t do anything after that with the numbers”</li> <li>• “Making <i>quantitative</i> observations of plants and assessing them.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Solution</b> | <p>When the participants mention a solution or a problem that is solved or a decision being made.</p> | <ul style="list-style-type: none"> <li>• “She had a problem and broke up how to find a <i>solution</i>. She then took the important information and implemented it into her <i>solution</i> idea.”</li> <li>• “She’s using mathematical-based <i>solutions</i> to solve her problem”</li> <li>• “Takes quantitative notes on what is occurring and reacts to problems with logical <i>solution</i>”</li> <li>• “The coffee shop owner tracked patterns and came up with a <i>solution</i> for a busy day of the week, demonstrating computational thinking”</li> <li>• “There is a problem expressed and the proposed <i>solution</i> is run in a computer with data.”</li> <li>• “Using abstraction and algorithms to get to a <i>solution</i>.”</li> <li>• “Yes, because she performed an analysis and drew a <i>conclusion</i>, then made changes based on it.”</li> <li>• “He is using trial and error to find the <i>solution</i>.”</li> <li>• “This line by line <i>solution</i> is a systematic approach that a computer could likely run.”</li> <li>• “This is a <i>solution</i> to a problem that a computer program could run in a similar manner.”</li> <li>• “This situation demonstrates Computational Thinking because by using trial and error it shows that she’s trying to create a <i>solution</i> to the problem.”</li> <li>• “By making the list and comparing the options she is thinking very logically and the <i>solution</i> will be presented when all the activates on those lists are compared.”</li> <li>• “Hannah’s situation demonstrates Computational Thinking because she is breaking down a problem into simpler pieces to help with her <i>solution</i> of deciding whether or not to attend graduate school.”</li> <li>• “She’s taking her thoughts and using <i>solutions</i> and comparisons to solve”</li> <li>• “There is a method for finding a <i>solution</i> in this situation but it involves personal experience and opinions for Hannah that a computer may not be able to generate.”</li> <li>• “Has a problem and using logical thinking to come up with a <i>solutions</i>”</li> <li>• “Yes, because she saw a problem and identified a <i>solution</i>.”</li> <li>• “This is a <i>solution</i> to a problem that a computer could execute.”</li> <li>• “Olivia is assessing her company website and forming <i>solutions</i> based on her feedback, which is</li> </ul> |

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|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                   |                                                                                                                                                                                                                                            | <p>computational thinking”</p> <ul style="list-style-type: none"> <li>• “He works in part to find his <i>solution</i>. He is looking for something to stand out in each section that would indicate the need for a certain solution.”</li> <li>• “Yes this demonstrates Computational Thinking because inspecting the pipe might include being able to test out, tweak and identify the problem in order to develop a <i>solution</i>.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Subjective</b> | <p>When the participant mentions or comments on the subjective or biased nature within the example such as mentioning opinions or how someone is feeling. However, not when the participant has subjective feelings about the example.</p> | <ul style="list-style-type: none"> <li>• “There is a method for finding a solution in this situation but it involves <i>personal experience and opinions</i> for Hannah that a computer may not be able to generate.”</li> <li>• “This method involves <i>human considerations</i> that a computer might not duplicate.</li> <li>• could be <i>subjective ratings</i>”</li> <li>• “He is just noting down his own <i>personal opinions</i> without doing any deep thinking”</li> <li>• “It is very <i>subjective thinking</i> without solid logic”</li> <li>• “it's just reviewing on <i>how he feels</i>”</li> <li>• “Matt is looking for patterns in his cooking to assess if he needs to make adjustments based on his <i>personal enjoyment</i> of the food, which is computational thinking”</li> <li>• “no because he is simply following the instructions and is noting <i>his opinion</i>”</li> <li>• “<i>stating how much he likes it</i> isn't thinking computationally”</li> <li>• “This is just <i>preference</i>.”</li> <li>• “Using a recipe to cook and then <i>writing about what he liked</i>”</li> <li>• “Yes, because despite taste being a <i>subjective measure</i>, he is still using data to analyze his cooking, making his actions in the end logical.”</li> <li>• “This problem-solving method involves <i>human opinion and subjective criteria</i> that a computer would not be able to provide.”</li> </ul> |
| <b>Thinking</b>   | <p>When they talk about <i>how</i> they were thinking.</p>                                                                                                                                                                                 | <ul style="list-style-type: none"> <li>• “She is analyzing data and uses that data in a way to solve a problem or improve a system. It requires <i>more thought process and creativity</i>”</li> <li>• “she takes down data, <i>thinks about it</i>, and makes a decision and action based on the data”</li> <li>• “Although he is recognizing patterns he did not go out of his way to look for these patterns they were presented naturally to him. He is also not trying to break apart the situation it is just what is happening. This is a schedule more than a <i>thought process</i>”</li> <li>• “Cole is observing, <i>not thinking</i> about what happens on his walk.”</li> <li>• “He just is observing things, <i>not thinking</i>.”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

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- “He probably isn't *actively thinking* about his environment”
  - “He *thinks through his daily routine* and takes note of timing”
  - “hes *not really doing any thinking* except for noting that some things happen at the same time every day”
  - “I selected "Yes" because I believe there was computation involved in this line of thinking. I would describe this as noticing a recurring pattern, or trend, which is both *critical thinking* as well as calculating time of occurrences.”
  - “While the situation involves data, Cole is not seen to do any *thinking about such data.*”
  - “Yes, because Cole made use of exact timing and *logical thinking.*”
  - “checking code is definitely *thinking like a computer*”
  - “Francis is *thinking deeply* about his code”
  - “Grace is *thinking computationally* about the recipe”
  - “she is trying to make it better so she is *thinking through each change*”
  - “She needs to *think deeply* about how the recipe could be improved and takes steps to make changes in order to improve it”
  - “Yes because she is demonstrating *thinking based on past performances* of the recipe to make a better one”
  - “By making the list and comparing the options she is *thinking very logically* and the solution will be presented when all the activates on those lists are compared.”
  - “Hannah is *thinking critically* about her options”
  - “Hannah is *thinking like a computer scientist*”
  - “She is *thinking hard* about the positive and negatives of different options”
  - “She's *taking her thoughts* and using solutions and comparisons to solve”
  - “Yes because she is *thinking logically and systematically* about her choices”
  - “Yes, Hannah is making decisions by weighing the factors that impact her decision. So this means that she is having to do *advanced thinking* about her decisions.”
  - “because she is just *organizing her thoughts*”
  - “Has a problem and using *logical thinking* to come up with a solutions”
  - “Lily isn't *thinking very deeply* about her assignments”
  - “no because she is not making data or doing *complex though*”
  - “No because she is simply copying dates into a planner. It doesn't require any creativity or problem solving or *meaningful thinking* besides her decision to start the process.”
  - “She doesn't really performs *critical thinking*, she just writes what she needs to do.”
-

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- “This *doesn't require much thought processing*. She just needs to know when the assignment is due and does not need to do any *further thinking*”
  - “Luisa is completing a task that *doesn't require much thought*”
  - “Luisa is typing words, but not necessarily *thinking about them*”
  - “No, because she wasn't using any math to do her work or very *advanced thinking*. Transcribing can be done mindlessly.”
  - “Not necessarily -- I'm sure there is a computation on the neurological level, but Luisa isn't *consciously computing anything*.”
  - “She *didn't need to think* about the process, she just typed what she heard”
  - “She does not have to *deeply process* the words spoken in the interviews to write up the transcription”
  - “She *isn't thinking* about what is being said, just writing things down.”
  - “There *isn't much thinking involved* when making a transcript other than maybe trying to understand what the people are saying. Although, when that happens, it is very straight forward and there is a correct answer.”
  - “Transcription is *less thinking*, more regurgitation.”
  - “He is just noting down his own personal opinions without doing any *deep thinking*”
  - “he is not really doing *heavy thinking*, and there isn't much information about what hes noting. if he was writing in-depth 5 paragraph essays on the tastes of the dish, then yes, but if hes just doing a 5 star system then its not.”
  - “It is very *subjective thinking* without solid logic”
  - “Matt isn't *thinking deeply* about the pastas”
  - “There is no *additional thought process* during the comment section.”
  - “no because she is simply adhering to what other people are suggesting her to do which doesn't require any problem solving or *complicated thinking* on her part.”
  - “Olivia is *thinking critically* about her website”
  - “She is modifying the website, like one would modify a program. It *requires thinking* to implement their suggestions.”
  - “yes, she is taking advice, *thinking about it*, figuring out how she can implement it, and implements it”
  - “He is just searching until he finds it which does not require any logic or *deep thought processing*”
  - “He is not using *deep thought processes* in order to find the pipe. He is just looking around and
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|                        |                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        |                                                                                                                                           | <p>hoping he finds it”</p> <ul style="list-style-type: none"> <li>• “The plumber is <i>thinking deeply</i> about the pipe”</li> <li>• “The preschoolers are <i>thinking critically</i> about the plants”</li> <li>• “They are just making observations and comparing, not really doing any <i>deep thinking</i>”</li> <li>• “Yes because it requires a <i>higher level of thinking</i> and involves problem solving”</li> <li>• “Yes, because they are writing a computer program that requires math and some form of <i>advanced thinking</i>”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Trial and Error</b> | When “trial and error” is explicitly mentioned or when there is no strategy in problem solving, mentioning a level of brute force method. | <ul style="list-style-type: none"> <li>• “<i>Going line by line</i> isn't really using your logic to figure out where the error possibly might be and narrow down how much code you have to check”</li> <li>• “He is using <i>trial and error</i> to find the solution.”</li> <li>• “He is using <i>trial and error</i>.”</li> <li>• “Yes - the <i>process of elimination</i> in each line is computational.”</li> <li>• “Yes, because he's <i>testing all the different areas where there could be errors</i>.”</li> <li>• “because she is using <i>try and error</i> not logic”</li> <li>• “following the recipe would be the example but when <i>tweaking it with unknown amounts</i>, it is not Computational Thinking.”</li> <li>• “<i>Grace edits the equation of ingredients until she gets the desired outcome</i>.”</li> <li>• “Grace isn't trying to narrow down the ingredients that could bring the best results - <i>she is trying every single combination which isn't efficient at all</i>.”</li> <li>• “She uses her intuition and evidence from previous recipes <i>to see what works and what doesn't</i>.”</li> <li>• “This situation demonstrates Computational Thinking because by using <i>trial and error</i> it shows that she's trying to create a solution to the problem.”</li> <li>• “Yes, because Grace is <i>tweaking the recipe which means she is adjusting the formula just enough each time and experimenting how this affects her bread</i>.”</li> <li>• “<i>He is just searching until he finds it</i> which does not require any logic or deep thought processing”</li> <li>• “He is not using deep thought processes in order to find the pipe. <i>He is just looking around and hoping he finds it</i>”</li> <li>• “Using a system to inspect the pipe instead of <i>randomly searching for the root of the problem</i>”</li> <li>• “Yes - by scanning the pipe, the plumber is <i>taking a process of elimination approach</i>, which is technically computation.”</li> </ul> |
| <b>Unsure</b>          | This is when                                                                                                                              | <ul style="list-style-type: none"> <li>• “Review isn't computational”</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

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the coder is  
unsure how to  
classify  
something.

- “Review”
  - “I selected "No" because Cole is referring to these situations as landmarks at a certain time.”
  - “yes because he is thinking about times and stuff”
  - “This does not demonstrate any of the steps of computational thinking”
  - “This is just a reminder.”
  - “This situation was thought out in an organized fashion such that everything will be taken care of in an even and fair way.”
  - “Yes, because they are having to format the information in a patterned way which even a computer can run through.”
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## **Results: Student Answers vs. Researcher Intention**

The first research question we intend to answer is: Do student answers largely match researcher designed intentions? With computational thinking, we recognize that the vignettes we designed can be interpreted differently with preconceived notions of an individual. In the student responses, they were prompted to either agree that the vignette is an example of computational thinking or not. From there, we took the percentage of students who agreed with our intended response to compare to those who disagreed.

Our four intended non-computational thinking vignettes (Cole, Luisa, Matt, Lily) were developed so participants could have a contrast with the vignettes that do embody computational thinking. In the Cole vignette, 51.4% of participants agreed that this vignette did not embody computational thinking. For the Luisa vignette, 85.7% of participants also agreed that this vignette was not an example of computational thinking. For the Lily vignette, 58.8% of participants found that it was not an example of computational thinking. In the Matt vignette, 58.8% of participants agreed with our intended response.

The eight researcher-intended computational thinking vignettes responses (Plumber, Francis, Preschoolers, Hannah, Olivia, Grace, Rich, Coffee) were also reviewed. Overall, the majority of participant responses agreed that these vignettes demonstrated components of computational thinking. 67.6% of participants agreed with our researcher-intended response in the Plumber vignette. In the Francis vignette, 70.6% of participants agreed with us. The Preschooler vignette had an agreement of 73.5% from participants. 83.3% of participants agreed with our researcher-intended answer in the Hannah vignette. In the Olivia vignette, 82.4% of participants agreed with the researchers. The Grace vignette had an agreement of 85.3% from participants. The Rich vignette also had a high agreement of 88.9% from participant responses. However, the Coffee vignette had a unanimous agreement from all the participants that this vignette does demonstrate components of computational thinking.

Below is the full table of agreement and disagreement from all the vignettes that were shown to participants.

| Vignette      | Intended Response | Student Agreement |              |
|---------------|-------------------|-------------------|--------------|
|               |                   | Agree             | Disagree     |
| <b>Cole</b>   | <b>No</b>         | <b>51.4%</b>      | <b>48.6%</b> |
| <b>Luisa</b>  | <b>No</b>         | <b>85.7%</b>      | <b>14.3%</b> |
| Matt          | No                | 58.8%             | 41.2%        |
| Lily          | No                | 58.8%             | 41.2%        |
| Plumber       | Yes               | 67.6%             | 32.4%        |
| Francis       | Yes               | 70.6%             | 29.4%        |
| Preschoolers  | Yes               | 73.5%             | 26.5%        |
| Hannah        | Yes               | 83.3%             | 16.7%        |
| Olivia        | Yes               | 82.4%             | 17.6%        |
| Grace         | Yes               | 85.3%             | 14.7%        |
| Rich          | Yes               | 88.9%             | 11.1%        |
| <b>Coffee</b> | <b>Yes</b>        | <b>100%</b>       | <b>0%</b>    |

## Results: Student Perception of Vignettes

The next research question we focused on was: Which themes emerge among student responses on the items with the most and least agreement? Deriving from the previous research question, three vignettes were noted. The Luisa (85.7%) and Coffee (100%) vignettes had the highest agreement between researcher and participant answers while the Cole (51.4%) vignette had the lowest agreement and greatest discourse between responses.

From the Luisa vignette, the difficulty of the task the subject of the vignette was discussed. Many participants mentioned that due to the task of transcribing interviews was not difficult, the vignette therefore did not demonstrate computational thinking. Deriving from the difficulty theme, many participants also mentioned other codes like thinking, analyzing information, and others as seen in the table below. We noticed that the other codes mentioned were due to the task in the vignette not having the components the codes represented. This absence of components goes back to the difficulty theme which only added to many participants' reasoning for answering that the Luisa vignette did not demonstrate computational thinking.

| Vignette | Codes                                        | Participant Responses                                                                                                           |
|----------|----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| Luisa    | Difficulty Thinking                          | Transcription is less thinking, more regurgitation.                                                                             |
|          | Decomposition                                | Did not break down a problem.                                                                                                   |
|          | Difficulty Thinking                          | Luisa is completing a task that doesn't require much thought                                                                    |
|          | Analyzing Information<br>Difficulty Thinking | She does not have to deeply process the words spoken in the interviews to write up the transcription                            |
|          | Decomposition<br>Problem Solving             | Luisa didn't solve the problem of transcribing the interviews by breaking it down into smaller problems she could solve easily. |
|          | Computation<br>Difficulty                    | Luisa was simply typing what she heard, she did not need to compute                                                             |

|                                     |                                                                                                                                                                                |
|-------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                     | anything from the conversations, such as hidden meaning or tone differences in the interview                                                                                   |
| Difficulty Problem Solving          | I chose "No" because Luisa is simply typing up transcriptions by watching online interviews, this doesn't require Computational Thinking and using problem-solving techniques. |
| Difficulty Thinking                 | She didn't need to think about the process, she just typed what she heard                                                                                                      |
| Analyzing Information Difficulty    | She is only listening and writing down what she hears, which doesn't require her to process the information                                                                    |
| Following Steps Pattern Recognition | No, because there is no pattern to follow.                                                                                                                                     |
| Problem Solving                     | No problem-solving                                                                                                                                                             |
| Difficulty                          | This is simply converting something from one form to another.                                                                                                                  |
| Difficulty Math Thinking            | No, because she wasn't using any math to do her work or very advanced thinking. Transcribing can be done mindlessly.                                                           |
| Difficulty Thinking                 | Luisa is typing words, but not necessarily thinking about them                                                                                                                 |
| Efficiency                          | No, she only did what she was supposed to be doing, didn't try to optimize it.                                                                                                 |
| Computation                         | not computing anything                                                                                                                                                         |
| Plan                                | No because Luisa already finished her project through typing every interview rather than come up with another plan.                                                            |
| Decomposition                       | This does not demonstrate any of the steps of computational thinking                                                                                                           |
| Computation Math                    | the other parts of her project may have involved computing things, but I have not been given that information.                                                                 |

|                                                                                                           |                                                                                                                                                         |
|-----------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                           | the one part i do know about, which is that she transcribed interviews, doesn't involve math                                                            |
| Difficulty Thinking                                                                                       | She isn't thinking about what is being said, just writing things down.                                                                                  |
| Difficulty                                                                                                | Not not computation thinking here more just autopilot working                                                                                           |
| Data QQ                                                                                                   | No because this is more qualitative then quantitative data                                                                                              |
| Organization                                                                                              | because there is no organizational part to it                                                                                                           |
| Abstraction<br>Algorithm<br>Analyzing Information<br>Difficulty<br>Following Steps<br>Pattern Recognition | She is not creating patterns, recognizing important information, or working with an algorithm. She is just following basic steps to complete a project. |
| Difficulty Observation                                                                                    | She "autonomously" watched these interviews and observed thoughts from others to create her own output.                                                 |
| Problem Solving                                                                                           | She doesn't seem like she's solving any problems out                                                                                                    |
| Difficulty                                                                                                | transcripts not computational thinking because it is just restating info                                                                                |
| Difficulty                                                                                                | No because this part of her project only requires copying words down and is a simple task                                                               |
| Analyzing Information<br>Difficulty<br>Observation                                                        | No, because she merely observed, and did not make an decision.                                                                                          |

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The Coffee vignette received an overwhelming agreement between all the participants who provided a response. Overall, most participants mentioned that because the subject of the vignette was analyzing information, the vignette demonstrated computational thinking. It seems that the manipulation and analysis of data constitutes as computational thinking to the participants in the Coffee vignette as well as using data to

come to a solution. The math code also appeared in the codes associated with the coffee vignette; many participants eluded that because the subject used math in their problem solving, the vignette is therefore demonstrating components of computational thinking. More of the codes that were presented can be seen below.

| Vignette | Codes                                                             | Participant Responses                                                                                                                        |
|----------|-------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| Coffee   | Math<br>QQ                                                        | She is using numbers to predict                                                                                                              |
|          | Abstraction<br>Algorithm<br>Solution                              | Using abstraction and algorithms to get to a solution.                                                                                       |
|          | Analyzing Information<br>Data<br>Logic                            | She is able to analyze the data to make a logical decision                                                                                   |
|          | Math<br>Problem Solving<br>Solution                               | She's using mathematical-based solutions to solve her problem                                                                                |
|          | Analyzing Information<br>Math<br>Problem Solving                  | yes she made a graph to figure out when she needs more staff.                                                                                |
|          | Analyzing Information<br>Pattern Recognition<br>Solution          | The coffee shop owner tracked patterns and came up with a solution for a busy day of the week, demonstrating computational thinking          |
|          | Analyzing Information<br>Documentation<br>Math<br>Problem Solving | Yes, this demonstrates Computational Thinking because creating a histogram and keeping track of information requires problem-solving skills. |
|          | Analyzing Information<br>Plan                                     | She analysis the input to project an output plan.                                                                                            |
|          | Analyzing Information<br>Data<br>Iteration<br>Thinking            | she takes down data, thinks about it, and makes a decision and action based on the data                                                      |
|          |                                                                   |                                                                                                                                              |

|                                                       |                                                                                                                                             |
|-------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Analyzing Information<br>Data                         | She analyzed her data in order to come up with her next decision                                                                            |
| Data<br>Plan<br>QQ                                    | plan of action and quantitative data                                                                                                        |
| Analyzing Information<br>Math                         | She made a graph to see how many customers she gets on certain days                                                                         |
| Computer<br>Data<br>Problem Solving<br>Solution       | There is a problem expressed and the proposed solution is run in a computer with data.                                                      |
| Computation<br>Computer<br>Data<br>Math               | This requires calculations and data visualization.                                                                                          |
| Analyzing Information<br>Difficulty<br>Math           | Yes, because the owner is doing math to figure out how many customers she has each day and she is doing this in a very advanced way.        |
| Data                                                  | The coffee shop owner is thinking computationally about the data                                                                            |
| Analyzing Information<br>Iteration<br>Solution        | Yes, because she performed an analysis and drew a conclusion, then made changes based on it.                                                |
| Computation<br>Math                                   | calculating customers per day                                                                                                               |
| Abstraction<br>Analyzing Information<br>Decomposition | Yes because she is breaking the problem down, taking only the information she needs to find out how many customers come in on certain days. |
| Pattern Recognition                                   | This, I believe, is pattern recognition                                                                                                     |
| Computation<br>Math                                   | graphing numbers of customers is definitely computing things                                                                                |

|                                                                          |                                                                                                                                           |
|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Analyzing Information                                                    | She gathers data and analyzes it.                                                                                                         |
| Documentation<br>Logic<br>Problem Solving<br>QQ<br>Solution              | Takes quantitative notes on what is occurring and reacts to problems with logical solution                                                |
| Analyzing Information<br>Data                                            | Yes because she is using data to make business decisions                                                                                  |
| Analyzing Information<br>Data<br>Logic                                   | because she is collecting data and analyzing the data logically                                                                           |
| Abstraction<br>Decomposition<br>Iteration<br>Problem Solving<br>Solution | She had a problem and broke up how to find a solution. She then took the important information and implemented it into her solution idea. |
| Abstraction<br>Data<br>Efficiency<br>Iteration                           | She took in very useful data from her customers and improved her work schedule in response                                                |
| Documentation<br>Problem Solving                                         | By recording work loads and fixing only that problem by getting a fixed improvement (1 person) it is thinking computationally.            |
| Computer<br>Math<br>Problem Solving                                      | She used a mathematical model to solve her problem.                                                                                       |
| Following Steps<br>Plan                                                  | She's going through steps to plan staffing                                                                                                |

|                                                                                         |                                                                                                                                                                   |
|-----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Analyzing Information<br>Computation<br>Math                                            | Absolutely! The coffee shop owner is quite literally computing the average amount of customers per day to help her understand how to better support her business. |
| Analyzing Information<br>Iteration<br>Plan                                              | using info collected to change her plan for the coffee shop                                                                                                       |
| Analyzing Information<br>Data<br>Difficulty<br>Iteration<br>Problem Solving<br>Thinking | She is analyzing data and uses that data in a way to solve a problem or improve a system. It requires more thought process and creativity                         |
| Data<br>Logic<br>Observation                                                            | Yes, because she used observation to gather data and made a logical decision based on that data.                                                                  |

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The Cole vignette was split almost halfway between participants who agreed with the researcher-intended response and those who disagreed. Students who agreed that the Cole vignette was not a representation of computational thinking noted, similarly to the Luisa vignette, that due to the subject not completing a difficult task, instead just observing, is enough of a threshold to not consider the vignette to be demonstrating computational thinking. However, for some participants, while Cole did not do anything with the information, just observing his surroundings, even thinking mathematically, was enough to consider the overall vignette to demonstrate computational thinking. Below are the codes associated with the participants' responses to the Cole vignette.

| <b>Cole Vignette Answer</b> | <b>Codes</b>                 | <b>Participant Responses</b>                                                                         |
|-----------------------------|------------------------------|------------------------------------------------------------------------------------------------------|
| Yes                         | Documentation<br>Observation | Because he's seeing the same occurrences at the same time each day, meaning that he is keeping track |

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|                                        |                                                                                                                                                                                                                                          |
|----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                        | of the time whenever he sees the golden retriever by the fountain or the man turning off the lights.                                                                                                                                     |
| Pattern Recognition Thinking           | I selected "Yes" because I believe there was computation involved in this line of thinking. I would describe this as noticing a recurring pattern, or trend, which is both critical thinking as well as calculating time of occurrences. |
| Observation<br>Pattern Recognition     | Cole pays attention to the details such as the time he sees these occurrences and observes that it's repetitive.                                                                                                                         |
| Pattern Recognition                    | Yes, because it is a very precise pattern.                                                                                                                                                                                               |
| Decomposition<br>Pattern Recognition   | Yes because it breaks down the steps Cole takes during his walk and shows patterns in what he sees everyday.                                                                                                                             |
| Pattern Recognition                    | Cole is experiencing pattern recognition                                                                                                                                                                                                 |
| Observation<br>Pattern Recognition     | Making observation and seeing patterns of things around him                                                                                                                                                                              |
| Pattern Recognition                    | because he is noticing the patterns                                                                                                                                                                                                      |
| Observation                            | He has noticed the same two events along his morning walk that always occur in a specific order and time                                                                                                                                 |
| Following Steps<br>Pattern Recognition | yes, it is very step by step and the events are always in the same order at the same time.                                                                                                                                               |
| Math<br>Rating                         | Cole is framing his daily walk in a mathematical sense. He is using numbers to explain his timeline.                                                                                                                                     |
| Documentation<br>Thinking              | He thinks through his daily routine and takes note of timing                                                                                                                                                                             |

|    |                                                  |                                                                                                                                                                                                                                                                   |
|----|--------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| No | Thinking                                         | Yes, because Cole made use of exact timing and logical thinking.                                                                                                                                                                                                  |
|    | Observation                                      | No because he is simply noticing information going on around him.                                                                                                                                                                                                 |
|    | Data Thinking                                    | While the situation involves data, Cole is not seen to do any thinking about such data.                                                                                                                                                                           |
|    | Problem Solving                                  | He's not actively trying to figure out any solutions to problems he's having                                                                                                                                                                                      |
|    | Problem Solving                                  | This is not a situation that demonstrates Computational Thinking because there is no problem-solving involved.                                                                                                                                                    |
|    | Decomposition<br>Pattern Recognition<br>Thinking | Although he is recognizing patterns he did not go out of his way to look for these patterns they were presented naturally to him. He is also not trying to break apart the situation it is just what is happening. This is a schedule more than a thought process |
|    | Observation<br>Thinking                          | He just is observing things, not thinking.                                                                                                                                                                                                                        |
|    | Computation<br>Observation                       | Cole is just observing things, he's not calculating or computing anything.                                                                                                                                                                                        |
|    | Analyzing Information<br>Observation             | He's observing, but he isn't coming to any conclusions or using the information in any useful way.                                                                                                                                                                |
|    | Observation                                      | No, because he is only observing things that happen around him at certain times                                                                                                                                                                                   |
|    | Observation                                      | This is simply observing, not thinking.                                                                                                                                                                                                                           |
|    | Observation<br>Problem Solving                   | There is no problem-solving involved in this situation, it is only observations being made.                                                                                                                                                                       |

|                                                  |                                                                                                                                         |
|--------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Problem Solving                                  | I don't think it's problem-solving related.                                                                                             |
| Analyzing Information<br>Observation             | No, he is only observing and not actually processing any information                                                                    |
| Documentation<br>Pattern Recognition<br>Thinking | hes not really doing any thinking except for noting that some things happen at the same time every day                                  |
| Observation<br>Problem Solving                   | This doesn't count as computational thinking because Cole isn't solving a problem, he is only observing that something occurs at x time |
| Analyzing Information<br>Observation             | He is only making an observation and not processing the information                                                                     |
| Observation                                      | It's just an observation.                                                                                                               |
| Pattern Recognition<br>Problem Solving           | While he is observing a pattern daily, there is no problem to be solved which is a part of computational thinking                       |
| Observation<br>Thinking                          | Cole is observing, not thinking about what happens on his walk.                                                                         |

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## **Overall Discussion, Limitations, and Future Directions**

### *Discussion*

Reading and qualitatively coding student responses have brought insight into the preconceptions students have about computational thinking. Through the responses, we noted that manipulation or analyzing data in any vignette will garner most participants to answer that there are components of computational thinking present. However, when that is taken away, like in the Cole vignette, it becomes less clear-cut. It becomes more apparent of the ambiguity of the definition of computational thinking as participants would use similar reasoning to come to different conclusions. This is similar to how other researchers have had different components that represent computational thinking when they define what it is in their lens. Students can have various skills that happen to be associated with computational thinking, but they may not be aware of that information.

### *Limitations*

While it is discussed in this paper that there is no assessment on computational thinking, we did not make that our focal point of our study. Through the search and development of the vignettes, we recognized that it is not the sole goal we should be working towards. However, this study and the vignettes are still in its early developments and have a lot of room for improvement. As we have mentioned previously, the vignettes we have currently developed do not have one concrete answer. Preconceptions can cause for there to be different interpretations of the vignettes presented. Also, while we did recognize a need to have a concrete definition of computational thinking, we did not achieve that through this study.

### *Future Directions*

We have many goals we want to achieve in the coming months with this work! First, we are interested in submitting to a conference in the near future. We also want to edit the vignettes we have. We noticed that some vignettes are a little longer than

others and various levels of detail. We want to develop a study that focuses on the differences in detail and how that may affect a student's response. Our team is also interested in looking at how technology played a role in student responses and if a student would be more likely to agree with the researcher-intended response if there was a clear technological component associated with a vignette.

A redeployment of the study would be done in the near future. In addition to the pre-established questions and the addition of demographic questions, we want to include a question asking participants how they would define computational thinking. This would allow us to understand more of their thought process and reasoning behind their explanations.

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