ASSESSING MIDDLE-SCHOOL TEACHERS' ATTITUDES AND USAGE OF CS UNPLUGGEDED

by

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ABSTRACT

Computer Science (CS) Unplugged is a set of activities that allow students to explore computer science concepts without using a computer. Prior research on the effectiveness of CS Unplugged classroom activities has focused primarily on student attitudes and learning outcomes. Teacher understanding and comfort level with the curriculum must also be considered when assessing whether CS Unplugged is a viable option in the classroom. We developed a set of lesson plans that fit a traditional middle school classroom and presented these lessons to teachers through a 2-day workshop. We used surveys and deployment reports to determine whether teachers would be comfortable with the CS Unplugged activities, whether they understood the underlying material, and whether they would use CS Unplugged in their classrooms. Through our research, it was found that teachers are comfortable with the Unplugged curriculum, have high levels of understanding of the material, and will use the Unplugged activities in their classrooms.

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DEDICATION

To my beautiful bride-to-be.

CHAPTER 1: INTRODUCTION

In 2015, Gallup, Inc., in conjunction with Google, surveyed students, parents, and teaching professionals on their respective perceptions of the field of computer science (CS) [1]. Out of 1,685 parents surveyed, 91% of the sample agreed that offering opportunities to learn computer science is a good use of a school's resources and 90% wanted their children to learn more CS concepts in the future [1]. In addition, the Bureau of Labor Statistics estimate that software jobs will grow by 18% from 2014 to 2024 [2]. Currently it is estimated that only a quarter of K-12 schools offer CS classes [3]. The results of both economic and social surveys have led the White House to create the "Computer Science for All" initiative [3], which will provide $4 billion to states and $100 million to schools to fund computer science programs [4]. We must, therefore, determine how to effectively teach CS to students at various grade levels.

A number of hurdles exist for teaching CS in classrooms. First, many science teachers do not hold a degree or certification in a related technical field [5]. This indicates that teachers are often asked to teach technical classes when they may not be prepared. Previous research shows that teachers without a CS background may be comfortable with the pedagogical aspects of teaching CS, but may not have sufficient knowledge of the technical aspects [6]. There is a need to assist teachers who are not comfortable teaching a technically dense subject in a way that doesn't compromise the material. One common misconception is that computer science is equivalent to programming. While programming is a core pillar of computer science, it is not the entirety of the field. Teaching computer science should incorporate the study of computation and its applications. In order to holistically teach computer science, one must understand the fundamentals of how computers can solve problems. This approach to problem solving, labeled as computational thinking, can be divided into five categories: data representation, decomposition, abstraction, algorithmic thinking, and pattern recognition [7]. By approaching computational problems with computational thinking, students are encouraged to figure out how to solve a specific problem, as well as how a problem may be solved in general.

CS Unplugged (Unplugged) are a collection of activities designed to allow teachers with little background in CS to effectively teach CS courses and computational thinking. Originally designed by a research team headed by Tim Bell at the University of Canterbury in New Zealand, these activities consist of standalone kinesthetic activities that each focus on particular concepts in CS. For example, in the Unplugged binary number activity, students explore the concept of binary numbers, the building blocks of all computing, by flipping cards that represents each digit of a binary number.

The Unplugged activities have been used in a number of settings to increase interest in computing [8]; however, upon researching the viability of using these activities in more traditional classroom settings, it was discovered that none of the activities provided sufficient coverage across Bloom's Taxonomy [9], a method that classifies learning objectives in education. To address these limitations, a research team at Colorado School of Mines (Mines) expanded the activities to create lessons that cover more learning objectives and also fit into a more traditionally structured classroom.

Previous research at Mines has focused on student attitudes and learning outcomes. The purpose of this thesis is to assess the viability of CS Unplugged in the classroom by considering teacher attitudes and adoption of the material. The three questions that this research addresses are:

- Do teachers feel confident teaching CS Unplugged activities?
- Do teachers understand the concepts being taught?
- Will teachers use CS Unplugged in their classrooms?

CHAPTER 2: LITERATURE REVIEW

This thesis builds upon prior work that has analyzed the use of CS Unplugged activities in the classroom. In addition, previous studies on training teachers in technical subjects are considered. Thus, the following literature review is categorized into two topics: CS Unplugged in the classroom and teacher development.

2.1 CS Unplugged in the Classroom

In “Computer Science Outreach in an Elementary School,” Lambert *et al*. deployed select CS Unplugged activities to 4th grade students in an outreach environment to see whether these activities increased the students’ interest in CS [10]. These activities were performed in the classroom by the research team, who had developed the deployment materials. Students were surveyed before and after the outreach events about their interest in CS. The results show that students were more interested in CS after participating in the outreach events.

Following the Lambert study, Taub *et al.* surveyed middle school students’ attitudes about CS after participating in CS Unplugged activities [11]. The attitudes rated views regarding CS on a like-dislike scale, as well as on good-bad, harmful-beneficial, pleasant-unpleasant and likeable-dislikable dimensions. Specifically, the research team wanted to know students’ responses to questions relating to the nature of CS, the work in CS, and the characteristics of computer scientists. Researchers surveyed 81 middle-school students who had not used any Unplugged activities. Their responses were used as a control group. Next, the researchers presented Unplugged activities to 13 middle school students, with 6 of the students volunteering to be interviewed by the research team. The interview results were compared against the mean scores of the control group survey. It was found that students initially overvalued the essentialness of the computer to CS, were often unable to see the connections between Unplugged and CS, and didn’t see a wide range of careers available in CS. The authors suggested that the

Unplugged activities needed to focus explicitly on the direct connections to CS and should point to the wide range of careers in CS.

In “A CS Unplugged Design Pattern”, Nishida *et al.* describe a framework for designing new Unplugged activities [12]. The paper analyzes the original Unplugged outreach activities and lists the program’s defining features such as the absence of computers, the inclusion of games and kinesthetic activities, heavy student participation, easy implementation, and a sense of story. The characteristics identified in this paper strongly influenced our research team as we expanded existing activities and created new ones.

Though CS Unplugged has been successfully deployed in outreach programs, less research has been conducted regarding how well Unplugged would work in a traditional classroom environment. Thies and Vahrenhold, from the Technical University of Dortmund in Germany, have published two relevant papers with specific focus on student learning outcomes.

In “Reflections on Outreach Programs in CS Classes,” Thies and Varenhold used Bloom’s taxonomy to see which cognitive processes were engaged by selected CS Unplugged activities [13]. By evaluating three activities (Finite State Automata, Searching, and Deadlock and Routing), the authors found that the Unplugged activities worked very well in helping students to understand and apply CS concepts, but did not give students much opportunity to remember what had been taught or apply higher level cognitive processes. The authors concluded that using the unaltered CS Unplugged activities in situations that go beyond a broad introduction was not sufficient. They recommended expanding the activities to reach higher levels of Bloom’s taxonomy and present a more realistic view of CS concepts.

Thies and Vahrenhold’s paper “On Plugging ‘Unplugged’ into CS Classes” measured the effectiveness of the CS Unplugged outreach activities in lower secondary education [14]. In this study, the Binary Numbers, Binary Search, and Sorting Networks activities were taught twice to two groups of students, initially as a full instruction and three weeks later as a brief review. Through teaching the modified Unplugged outreach activities, the research team showed that there was no statistically significant difference in post-activity assessments between the Unplugged activities and alternative CS materials that covered the same topics. Assessments measuring learning outcomes across the Structure of Observed Learning Outcome (SOLO) taxonomy, a method that scores student understanding by looking at bits of a student's work, were also given to the students the day after the initial lesson and three weeks after the review session. The results showed that more students using the Unplugged activities achieved the *relational* operational state (second highest of five levels). These results reaffirm the authors' conclusion from their previous paper that CS Unplugged is suitable for use in the classroom, but additional teaching units and materials are required to meet the learning objectives.

"Computational Thinking: Expanding The Toolkit" is a brief summary of a set of tools to support computational thinking curriculum initiatives as presented to 24 teachers during a two-day workshop sponsored by Google's CS4HS program [15]. The tools were LEGO Mindstorms NXT, Scratch, App Inventor, and CS Unplugged. Each tool was explained in separate sessions of between 1.5 and 4 hours. Participants were surveyed at the beginning of the workshop, and at the end. Initially, attendees had very little knowledge of any of the computational thinking tools. After the workshop, when specifically asked about the Unplugged activities, 91% of the teachers stated that they were "likely" or "very likely" (4 and 5 on the Likert scale, respectively) to incorporate Unplugged activities into the classroom. This research shows not only that CS teachers are likely to use Unplugged in their classrooms, but also that a workshop is effective in helping teachers feel like they can use Unplugged.

2.2 Teacher Development

Ultimately, teachers are responsible for implementing changes in teaching. “The Role of Teachers in Implementing Curriculum Changes” examines teachers’ roles and attitudes after implementing new curriculum or standards [16]. The specific focus of the research in [16] was to observe and gather anecdotal evidence of New Zealand high school teachers’ experience after teaching a new CS curriculum. Through anecdotal evidence returned by surveys, the authors identified several road blocks to professional development and new curriculum implementation in CS secondary education. These hurdles included a lack of available resources, such as lesson plans, difficulty finding quality material appropriate for familiarizing themselves with the topic, and the need for more beginner-level explanation, support, and practice. The authors concluded that the teachers were intrinsically motivated to “provide better opportunities for students.” This research confirmed that there is a need to focus on making strong connections to career opportunities for the students when creating resources for teachers to appeal to teachers’ intrinsic motivation.

Ni and Guzdial in “Who Am I? Understanding High School Computer Science Teachers’ Professional Identity” detail an exploration into the professional identity of high school CS teachers [17]. As opposed to other teachers whose subjects fall within core curriculum, high school CS teachers do not usually belong to a computing department, and standards for computing courses often do not exist. A strong professional identity, which has been shown to be an indicator of a quality teacher, is hard to create or maintain in this environment. The paper suggests that providing a community in which CS teachers can share information and resources will help teachers to feel more comfortable in their job. Attending workshops (e.g., a CS Unplugged workshop) gives teachers the opportunity to interact with their peers while learning new material to implement in their curriculum.

As mentioned in the introduction, many secondary CS teachers are not trained in computing. Thus, when talking about the development of CS Unplugged classroom extensions, it is important to keep teachers' limited prior knowledge in mind. "Can You Learn to Teach Programming in Two Days" describes a pilot project intended to assist former teachers of Microsoft Office to transition to teaching CS [6]. This transition was required due to new mandatory standards for "digital technologies" at the national level. As it was difficult for secondary education teachers in more rural areas to spend one or two semesters away from the classroom for training, and since online training did not seem to be effective, the pilot facilitated a two-day intensive workshop that taught a simple visual programming language. Although teachers were able to learn the language during the workshop and planned to use it in their classrooms, one conclusion of the study was that the two-day workshop needs to be supplemented with some kind of continuing follow up. Thus, when administering workshops for Unplugged, it is important to ensure that participating teachers have the resources they need to implement the curriculum effectively.

In "Questions on Spoken Language and Terminology for Teaching Computer Science", Diethelm and Goschler look at the differences in vocabulary of K-12 teachers and their students with regards to teaching CS [18]. The paper seeks to raise awareness of the importance of human language in CS education. It distinguishes between using human language as a means to talk about CS concepts and the actual learning of computer programming languages. These terms can have CS meanings that are not always directly related to their common language usage (e.g. a 'bit' in the English language means "a small portion" while a 'bit' in CS is a single binary digit). This distinction in CS language can be particularly difficult for non-native speakers. While surveys indicate that many teachers are not immediately aware of this problem, they do realize that it could be a problem upon further consideration. Also, the severity of the issue varies based on the grade level taught and the level of abstraction of CS concepts. Thus, when developing CS curriculum, it is important to intentionally define clear and correct vocabulary so that teachers without in-depth technical knowledge are able to teach unhindered. Adding vocabulary cheat sheets to the Unplugged lesson plans is one technique we use to address this issue.

CHAPTER 3: APPROACH

Our approach to answering our research questions included a) ensuring the materials describing the Unplugged activities are comprehensive and clear, b) presenting the materials during a 2-day summer workshop, and c) gathering feedback from teachers regarding their actual deployments of the Unplugged activities and any remaining issues with the training materials. The development of our approach considered the previous research outlined in Section 2.2. The ways in which we worked on the clarity and content of the Unplugged activities were influenced by the research conducted by Lambert *et. al.*, Taub *et. al.*, Thies and Varenhold, and Diethelm and Goschler on the original Unplugged outreach activities. We decided to do a workshop based on the success of the work conducted in "Computational Thinking: Expanding The Toolkit" and "Who Am I? Understanding High School Computer Science Teachers' Professional Identity".

This research is primarily built upon work done by the research team at Mines over the past three years. Section 3.1 describes the prior work that relates to this thesis. Section 3.2 describes surveys that were conducted to gather feedback from teachers on the Unplugged activities and lesson plans. Section 3.3 summarizes the work that was done as a part of this thesis (i.e., to prepare the lesson plans and supplemental materials for teachers to use when deploying the activities). Lastly, Section 3.4 describes how we made Unplugged activities and supplementary activities available to teachers.

3.1 Prior Work

To address concerns that the Unplugged activities were not rigorous enough for middle school [14, 16, 15, 15, 17] and did not relate sufficiently to career options in computing [11], the Mines research team developed career and content extensions for four of the Unplugged activities. These activities were pilot tested in mixed grade-level classrooms during spring semester 2014.

During fall semester 2014 and spring semester 2015, the team developed two new activities and three content extensions, created worksheets to assess student understanding, and removed several of the less successful activities and extensions. The revised activities were pilot tested in 6th and 7th-grade classrooms. The team also mapped the activities to computational thinking skills and developed more comprehensive assessment instruments during the spring of 2015. These instruments were then pilot tested in summer camps during summer 2015.

The main thrust of the fall 2015 semester was assessing what students were learning via the Unplugged activities. The assessment consisted of projects completed before and after the activities were deployed, as well as worksheets completed as part of the deployments [19]. Results of these assessments were encouraging, but highlighted a number of issues both with the assessment instruments and the Unplugged activities.

To address the identified issues, the team carefully reviewed every lesson plan and worksheet to increase engagement and focused on improving content understanding during the spring of 2016. This was achieved by revising the lecture content, modifying worksheets to focus explicitly on important concepts, and streamlining the activities to remove confusion. As part of this effort, the lesson plans were reviewed in detail so that the activities could be deployed more easily, both by the research team and by teachers. Using the revised activities and worksheets, the final deployment of the activities during spring 2016 showed marked improvement in students' understanding of the content [20].

3.2 CS Unplugged Activities

By the end of spring 2016, well-crafted lesson plans had been developed for the following activities: Binary Numbers, Cryptography, Finite State Automata (FSA), Searching, Minimum Spanning Trees (MST), Parity and Error Detection, Artificial

Intelligence (AI), Image Representation, Computer Vision (CV), Sorting, and Deadlock and Routing. We discuss each of these activities briefly in the following subsections.

3.2.1 Binary Numbers

This activity explores the fundamentals of number representation, specifically binary numbers. Binary numbers are sequences of base-2 digits (1's and 0's) that are used to represent information. Binary numbers are intrinsic to computer science as any piece of information handled by a computer is ultimately represented as a binary number. Students use flip-cards (cards with a number of bits displayed) to learn how to count in binary and to understand the range of values that can be represented by a 5-bit (binary string length) number. Students are then introduced to the concept that base-10 numbers can be represented in binary with more bits. Finally, students complete a worksheet with six questions related to binary numbers, counting in binary, and converting between binary and decimal.

3.2.2 Cryptography

This activity gives students an introduction to cryptography, which is the study of securely encoding and decoding information. The activity introduces a simple method known as the Caesar cipher, which shifts the letters of the alphabet such that "ABCDEF" becomes "CDEFGH". For example, encoding the word "BAD" using this method would result in "DCF". The students are introduced to this scheme and are given a worksheet to practice encoding and decoding messages. The students then participate in a group activity that encourages each student to create their own Caesar cipher and interact with other student's ciphers under a "surprise party" narrative. Finally, the students engage in a guided discussion on how cryptography relates to real-world concepts.

3.2.3 Finite State Automata (FSA)

This activity gives students an introduction to Finite State Automata (FSA). FSA are machines that perform a predetermined sequence of actions depending on the sequence of inputs with which they are presented. Vending machines, elevators, turnstiles, and traffic lights are all examples of FSA, as they function differently depending on their state (e.g., has a coin been inserted?, are there cars waiting at the light?, has someone pushed a button?). Students are introduced to this concept through a group kinesthetic activity in which one member of the group (in the guise of a crazy fruit vendor) is given a set of instructions that translate into an FSA, and the other group members try to determine the fruit vendor's pattern. Students are then introduced to more formal FSA notation and given worksheets that ask them to analyze the behavior of a robot dog (presented as an FSA) Lastly, students are asked to design an FSA for a robot that performs chores.

3.2.4 Searching

The searching activity introduces the binary search algorithm to students. Binary search is a method that a computer can use to efficiently find an item in a linearly sorted list. By always comparing the middle element of the list to the target element, half the list can be eliminated with each comparison. Students are introduced to this concept via a dynamic demonstration using a sorted collection of numbered ping pong balls. To practice the technique, pairs of students complete a worksheet in which they must correctly perform a binary search in order to save their cows from an attacking dragon.

3.2.5 Minimum Spanning Trees (MST)

A Minimum Spanning Tree is a way to connect all the nodes in a graph in the most inexpensive way possible. For instance, if a city needs to connect every house via roads, but has a minimum budget, the city could make a minimum spanning tree to connect all of the houses. This lesson introduces Kruskal's algorithm, which is a method to construct a guaranteed minimum spanning tree from a graph. Students complete worksheets and participate in kinesthetic group activities that help teach Kruskal's algorithm.

3.2.6 Parity and Error Detection

Error detection is a method to ensure good transmission or storage of data. A simple type of error detection, known as parity, counts the number of 1s in a binary string and adds either a 1 or a 0 at the end of the string in order to ensure the string contains an even number of 1s. For example, the binary number "100" would be turned into "1001" with this scheme. This concept is introduced to students through a magic trick in which parity is used to identify a card in a grid that is flipped by a student. A worksheet is then given to the students to practice error detection.

3.2.7 Artificial Intelligence (AI)

AI is the study of how machines can mimic human intelligence. The primary activity in this lesson is a Turing test in which two students hidden from the class answer questions. One student is given a set of answers to model a computer, while the other student answers questions in their own words. The remaining students try to guess which answers are from the "computer". Students then play tic-tac-toe using an "intelligent" piece of paper with explicit instructions that ensure the paper cannot lose. This activity includes whole-group discussions and has no individual worksheets.

3.2.8 Image Representation

Image representation deals with how computers represent images with binary strings. Students are shown how black-and-white images can be represented as strings of binary numbers. Students are then introduced to image compression where strings with repeating patterns of 1s and 0s can be condensed into smaller pieces of information. Students walk through the process of image representation as a group, and then explore the concept further through individual worksheets.

3.2.9 Computer Vision (CV)

CV is the subject of how computers can “see” and interpret objects. Computers are able to detect edges and objects by calculating the differences in light and dark between areas of an image. Students explore this concept via two edge detection worksheets. This lesson includes discussion on how some programs will categorize objects using standard shapes.

3.2.10 Sorting

The sorting lesson introduces students to how computers sort objects in a list. The students are introduced to two sorting methods (insertion and selection sort). These methods are explored through several full class kinesthetic demonstrations and a small group activity.

3.2.11 Deadlock and Routing

Deadlock and Routing deals with how people download information from the Internet. In the Internet, there exists a web of connected devices, known as routers, that deliver information such as images, movies, music, and other files to clients. Students are introduced to the mechanics of this system through a kinesthetic activity that designates a handful of students to work as routers while the remaining students try to “download” images by asking the routers to retrieve bits of information on their behalf. Students are then encouraged to explore the concept further through a worksheet revolving around delivering mail from one town to the next through a series of post offices. Lastly, students are shown example situations where deadlock occurs (and needs to be avoided).

3.3 Formative Evaluation of CS Unplugged Lesson Plans

After the formal lesson plans were created, the research team then coordinated with teachers at STEM School & Academy to gain feedback regarding the suitability of the lesson plans and activities for deployment in their classrooms. Two surveys were given to three teachers (two 7th grade teachers and one 6th grade teacher). The lesson plan survey was completed after the teacher had read the lesson plan for an activity but before the lesson was deployed. The deployment survey was completed after observing the middle school students interacting with the lesson. The 7th grade teachers evaluated the Binary Numbers, Cryptography, Finite State Automata, Searching, Minimum Spanning Trees, and Parity and Error Detection lesson plans and activities. The 6th grade teacher evaluated the AI, Image Representation, CV, and Sorting lesson plans and activities. No teacher evaluated the Deadlock and Routing activity.

3.3.1 Lesson Plan Survey

The first survey focused on the lesson plan and assessed each teacher's level of comfort with the content and format. The purpose of this survey was to identify areas in each lesson plan that needed to be improved.

First, teachers were asked how comfortable they would be with each individual component of the activity, including classroom discussions, kinesthetic activities, and worksheets. The comfort level was rated on a four-point Likert-scale, with the four options being "Very Uncomfortable" (1), "Uncomfortable" (2), "Somewhat Comfortable" (3), and "Very Comfortable" (4). Teachers were then asked to assess the strength of the lesson's real world connections. This question was rated on a three-point Likert-scale, with the options being "Weak" (1), "Somewhat Strong" (2), and "Strong" (3). The teachers were also asked for additional comments regarding the lesson plans. Analysis of the feedback for each activity's lesson plan is included in Sections 3.3.4. Appendix A contains the survey data.

It is important to note that, although this was the first time each teacher had seen the lesson plans, one teacher had previously observed the activities. Thus, there may exist some favorable bias regarding comprehension of the underlying material for one teacher.

3.3.2 Deployment Survey

The second survey focused on the in-class deployments administered by the research team. The purpose of this survey was to obtain teacher feedback from watching the live lesson. The initial questions of each survey matched the corresponding lesson plan survey and were used to determine whether there was any change in a teacher's level of comfort with the individual components of the activity. These questions were followed by three short answer questions that asked whether the teacher would modify the activity in any way, how engaged students were with the activity, and whether the real-world connections were sufficient. Analysis of the feedback for each activity's in-class deployment is included in Sections 3.3.4. Appendix B contains the survey response data.

3.3.3 Semi-Structured Interview

Upon completion of the deployments, we organized a wrap-up interview with the three participating teachers. The purpose of this interview was to review the lesson plan and deployment surveys and clarify any comments and concerns the teachers had with the content and presentation of CS Unplugged. The results are reflected in the activity feedback sections that follow.

3.3.4 Formative Assessment of Activities

Using information from the lesson plans, post-deployment surveys, and the semi-structured interview with teachers, we identified areas that needed improvement in content and in supplemental material. The following sections are organized by activity and describes the issues identified and additional improvements that needed to be made to the activities. Some comments were common across multiple activities. These comments are described under General Feedback in the next subsection. The modifications made as a result of the comments received from the initial teacher feedback are listed in Section 3.4.

3.3.4.1 General Feedback

The surveys and interviews revealed that the teachers had some difficulties fully understanding the kinesthetic activities from the written lesson plans. Though the comfort levels for the kinesthetic group activities were high in the lesson plan surveys, the comfort levels of the teachers towards some of the kinesthetic activities dropped after the teachers observed the activities being used in the classroom. The activities that saw a decrease in comfort level were the kinesthetic activities that did not have a video demonstration created by Tim Bell. Interviewing the teachers confirmed this issue. Therefore, video demonstrations were created for almost all the kinesthetic activities that did not have a video demonstration (all except for the large group activities for Binary Numbers and Searching). In addition, the importance of watching these video demonstrations are now stressed in the written lesson plans, as the teachers who previously reviewed the lesson plans often reported that they didn't watch the existing video demonstrations. A step-by-step guide of each kinesthetic activity was also created as a supplement to each activity found in the lesson plans. In addition, one of the teachers mentioned that the Binary Numbers lesson plan didn't have very clear learning objectives. Though this comment wasn't found on any other lesson plan, we decided that it would be useful to include a clearly defined dedicated section that outlines the learning objectives for each lesson plan. Finally, although no teacher reported any issues, all lesson plans were reviewed generally for spelling and grammar errors.

3.3.4.2 Binary Numbers

Both 7th grade teachers stated that they were very comfortable with the group discussion and worksheets, but only somewhat comfortable with the kinesthetic activity. When asked about the strength of the lesson's real world connections, one teacher rated it as strong and the other teacher rated it as somewhat strong. Observing the lesson being deployed in the classroom made no difference in the comfort level of the teachers.

3.3.4.3 Cryptography

Both 7th grade teachers stated that they were very comfortable with the group demonstration and worksheets, but only somewhat comfortable with the introductory discussion. We then realized that the teachers were never supplied with an introduction to cryptography in the lesson plan. When asked about the strength of the lesson's real world connections, one teacher rated it as strong and the other teacher rated it as somewhat strong. Observing the lesson being deployed in the classroom made no difference in the comfort level of the teachers.

3.3.4.4 Finite State Automata (FSA)

Both 7th grade teachers stated that they were very comfortable with all areas of the lesson plan. When asked about the strength of the lesson's real world connections, one teacher rated it as strong and the other teacher rated it as somewhat strong. Observing the lesson being deployed in the classroom decreased the comfort level of both teachers. Specifically, the teachers mentioned that they felt less comfortable with the group kinesthetic activity.

3.3.4.5 Searching

Both 7th grade teachers stated that they were very comfortable with the group demonstrations, somewhat comfortable with the Raffle Ticket worksheet, and uncomfortable with both the Dragons and Cows worksheet and the Lion Hunting discussion. When asked about the strength of the lesson's real world connections, one teacher rated it as strong and the other teacher rated it as somewhat strong. Observing the lesson being deployed in the classroom increased the comfort level of both teachers.

3.3.4.6 Minimum Spanning Trees (MST)

Both 7th grade teachers stated that they were very comfortable with the DIY MST kinesthetic activity. One teacher stated that they were very comfortable with the Muddy City, while the other teacher only felt somewhat comfortable. Both 7th grade teachers stated that they were somewhat comfortable with the discussion about the real world connections and the Halloween Candy worksheet. When asked about the strength of the lesson's real world connections, both teachers rated it as strong. Observing the lesson being deployed in the classroom increased the comfort level of both teachers.

3.3.4.7 Parity and Error Detection

Both 7th grade teachers stated that they were very comfortable with the group demonstration and all of the group activities. One of the teachers said that they were very comfortable with the ASCII worksheet, while the other teacher said that they were only somewhat comfortable with the ASCII worksheet, citing a desire to know more about how parity works with ASCII in the real world. When asked about the strength of the lesson's real world connections, one teacher rated it as strong and the other teacher rated it as somewhat strong. Observing the lesson being deployed in the classroom increased the comfort level of both teachers.

3.3.4.8 Artificial Intelligence (AI)

The 6^{th} grade teacher stated that she was very comfortable with the group demonstration and all of the worksheets. The teacher stated that she was somewhat comfortable with the Intelligent Piece of Paper activity. When asked about the strength of the lesson's real world connections, the teacher rated it as strong. Observing the lesson being deployed in the classroom increased the teacher's comfort level with the Intelligent Piece of Paper activity.

3.3.4.9 Image Representation

The 6^{th} grade teacher stated that she was somewhat comfortable with all aspects of the lesson. When asked about the strength of the lesson's real world connections, the teacher rated it as somewhat strong. Observing the lesson being deployed in the classroom made no difference in the comfort level of the teacher.

3.3.4.10 Computer Vision (CV)

The 6^{th} grade teacher stated that she was very comfortable with the Edge Detection worksheets and somewhat comfortable with the Image Recognition worksheet and the discussions. When asked about the strength of the lesson's real world connections, the teacher rated it as somewhat strong. Observing the lesson being deployed in the classroom increased the teacher's comfort level with the lesson.

3.3.4.11 Sorting

The 6^{th} grade teacher stated that she was somewhat comfortable with the class demonstration and the Sorting Colors worksheet and uncomfortable with the class discussion.   When asked about the strength of the lesson's real world connections, the teacher rated it as weak. Observing the lesson being deployed in the classroom made no difference in the comfort level of the teacher.

3.4 Summary of Improvements

From our analysis of the teacher surveys, we identified areas in each activity and the curriculum as a whole that needed improvement. This section summarizes the changes and enhancements that were made to the lesson plans. The following activities received only the improvements listed under General Feedback (i.e., add cheat sheet, improve lesson objectives, edit grammar and spelling): Binary Numbers, Finite State Automata, Searching, Minimum Spanning Trees, Parity and Error Detection, AI, CV, and Image Representation. In addition, Table 1 provides a list of the supplemental videos that we created

Table 3.4: List of improvements made

Activity	**Video**
Binary Numbers	Binary Go Fish Demonstration
FSA	Fruit Vendor Demonstration
MST	DIY MST Demonstration
Image Representation	Encoding Race

3.5 Introducing Teachers to CS Unplugged

A primary goal of this research effort was to encourage middle school teachers to use CS Unplugged activities in their classrooms. Up until this point, we had only pilot tested the activities in three schools, with Mines students (graduate and undergraduate) presenting the materials. This section describes our efforts to reach a wider audience.

3.5.1 Summer Workshop

After the materials were developed, we hosted a CS Unplugged workshop and introduced willing teachers to the activities. The workshop took place during August 1st and 2nd, 2016. Teachers who attended the workshop were introduced to all of the lesson plans, along with supplemental presentations that relate computer science to real world application. The workshop agenda can be found in Appendix C.

3.5.2 Website

As a result of previous research done by the team at Mines, a website that hosts Mines' CS Unplugged materials has been created. As part of this research effort, the website was updated to host the modified curriculum. This website can be accessed at toilers.mines.edu/CS-Unplugged/.

CHAPTER 4: METHODOLOGY

With the refined curriculum and lesson plans in place, the next step was to collect and analyze data to determine our level of success in convincing middle school teachers to use CS Unplugged in their classrooms. In this section we begin by identifying our data sources. We then address how the data sources relate to each of our research questions.

4.1 Data Sources

Six sources of data were used to answer our research questions:

- After each activity was shown during the workshop, teachers completed an activity survey (referred to hereafter as *Activity Survey*). A sample is included in Appendix D. The relationship between the data and the research questions are described in Section 4.2.
- The activity worksheets completed by the teachers during the workshop were collected (*Worksheets*). These worksheets vary for each activity and are posted on the CS Unplugged website.
- After viewing all the Unplugged activities, teachers were asked to complete a comprehensive final project assessment (*Final Project*) covering the material. As described in Section 3, this assessment was developed by a former Mines graduate student to evaluate student learning outcomes and was substantially improved during additional deployments [19] [20]. A sample final project is included in Appendix E.
- At the end of the workshop, participants were asked to complete a final survey (*Workshop Survey*), which is included in Appendix F.
- Teachers who deployed Unplugged activities submitted experience reports (*Experience Report*). A sample of an experience report is included in Appendix G.
- All teachers who deployed activities participated in a semi-structured interview. The purpose of this interview was to allow teachers to elaborate on their

experiences using the Unplugged materials. The interview was structured to encourage more long-form and verbose answers than questions asked in the workshop survey or experience report. The interviews were recorded with the participants' consent. A sample copy of the assent script and interview questions are shown in Appendix H.

4.2 Research Evaluation

The following sections map the questions from our assessment instruments to our research questions. Several of the open-response questions directly map to various questions and are described in Section 4.2.4.

4.2.1 Do teachers feel confident teaching CS Unplugged activities?

The *Activity Surveys* were used to gauge the teachers' level of confidence immediately after learning the material. Three questions specifically relate to this research question:

- How comfortable are you with the material?
- How comfortable would you be using this activity in your classroom?
- How comfortable are you with the logistics of this activity?

Responses from these Likert-scale questions were converted to a weighted average to determine the general level of comfort for each activity.

Two questions on the *Experience Report* also related directly to this research question:

- How comfortable were you when deploying the activity?
- How confident are you that you could accurately grade the worksheets (if any)?

Responses from these Likert-scale questions were also converted to a weighted average to determine the general level of comfort for each activity.

The semi-structured *Interview* also included questions that potentially relate to confidence:

- Were these activities easy to deploy?
- How prepared did you feel to teach these activities?

4.2.2 Do teachers understand the concepts being taught?

Determining whether teachers understand the CS concepts is potentially challenging, since self-reports on levels of understanding are known to be highly subjective and inaccurate. Thus, a *Final Project* assessment was used to help us answer this research question. To assess student learning during prior CS Unplugged pilots, two versions of the project were administered as pre/post-tests. For the teachers, however, we were not as concerned with how they acquired the knowledge (i.e., whether they already knew the concepts or whether they learned them via the workshop), just that they could understand the material well enough to deploy the activities. In addition, the *Worksheets* completed by teachers were collected to ensure that teachers were able to correctly perform the required tasks.

Rubrics have previously been developed for both the Final Project and each Worksheet. The rubrics describe how we scored answers to questions as “Proficient”, “Partially Proficient”, and “Unsatisfactory”. Two evaluators scored each assessment and worksheet according to their respective rubric. Discrepancies in scoring, if any, were discussed and resolved (e.g., by accepting alternate solutions).

For teachers who implemented Unplugged activities in the classroom, the *Experience Reports* helped us gauge the teachers’ understanding of the material from answers to the following Likert-scale question:

- How would you rate your understanding of the material when presenting it to your class(es)?

We note, however, that the main source for this research question was from scoring of the *Final Project*, as it was the most objective.

4.2.3 Will teachers use CS Unplugged in their classrooms?

A teacher was considered to have "used" Unplugged in the classroom if they implemented one or more of the CS Unplugged modules in their classroom. The number of teachers who used CS Unplugged in their classroom was compared against the number of teachers who declined to use CS Unplugged. Additional statistics such as what activities were used, how many activities were used on average, etc. were also collected and will be presented when discussing Unplugged usage in the classroom.

In addition to counting how many teachers used CS Unplugged in the classroom, it was important to know why a teacher did not deploy a given activity. For each activity demonstrated in the workshop, the *Workshop Survey* asked teachers about their deployment plans. For each activity, teachers selected from the following options:

a) Will definitely deploy
b) Likely to deploy
c) Considering/Not sure
d) Will not deploy because activity doesn't relate
e) Will not deploy because activity is not engaging
f) Will not deploy because the material is confusing/unclear
g) Will not deploy due to lack of time in curriculum
h) Will not deploy (other)

Teachers who rated their likeliness to deploy an activity as "Will not deploy (other)" were encouraged to elaborate in paragraph form. The *Workshop Survey* only collected teachers' intentions. More important to this question is whether teachers actually used the activities in their classrooms. Thus, usage statistics were gathered based on the submitted *Experience Reports.*

We note that teachers were offered a stipend of $200 for any activity they deployed prior to October 1, 2016. Although this is standard research practice and, in essence, compensates the teachers for the time spent learning and preparing for the activity, it is also a source of bias. Thus, as part of the *Experience Report*, teachers were asked if they would use the activity again as a Yes/No/Maybe question. Answers to this question were the ultimate source in answering whether or not teachers will use CS Unplugged in their classrooms.

4.2.4 Open Response Questions

In the *Activity Survey*, *Workshop Survey*, and *Experience Report,* teachers had the ability to express or expand upon thoughts relating to the Unplugged curriculum, the workshop, and the activities. After data was collected, two evaluators categorized the open-response answers. One researcher reviewed the responses and categorized them thematically. The second researcher reviewed the identified categories and verified the classifications of the responses based on their themes. Discrepancies in classification, if any, were discussed and resolved.

For the Semi-Structured Interview, one researcher read through all the transcripts and compared the responses to those obtained from the Experience Reports. Since the purpose of the interview was to gather feedback not obtained from other sources, only answers that provided additional perspective were analyzed and summarized in paragraph form.

CHAPTER 5: RESULTS

The results collected from the CS Unplugged workshop and the participating teachers' deployments can be categorized according to which research question those results answer:

- Do teachers feel confident teaching CS Unplugged activities?
- Do teachers understand the concepts being taught?
- Will teachers use CS Unplugged in their classrooms?

The following sections present the results related to each of these questions. An analysis of the results is presented in Chapter 6.

5.1 Teacher Confidence

If teachers are not confident about their understanding of the material or the structure of an activity, they will be less likely to deploy it in their classrooms. This section presents teachers' level of comfort during the workshop and after deployment.

5.1.1 Workshop Results

Teachers' levels of confidence and comfort were assessed at the end of every lesson plan. The following questions related to comfort were asked on the workshop survey:

- How comfortable are you with the material?
- How comfortable would you be using this activity in your classroom?
- How comfortable are you with the logistics of this activity?

The teachers were asked to respond to the questions using Likert-scale responses from 1 to 5, with the five options being "Extremely Uncomfortable" (1), "Uncomfortable" (2), "Somewhat Comfortable" (3), "Comfortable" (4), and Extremely Comfortable" (5).

The average responses are classified according to Table 5.1. This table is somewhat arbitrary, but allows us to categorize and interpret the averages.

Table 5.1: Categorization of comfort levels

Comfort Levels	**Range**	**Justification**
“Extremely High”	4.75 – 5	A number of teachers indicated highest level of comfort (5)
“High”	4.25 – 4.75	Most teachers selected 4 or 5
“Moderate”	3.75 – 4.25	Most teachers selected 4, with some selecting 3
“Comfortable”	< 3.75	Many teachers did not report a high level of comfort

5.1.1.1 Results By Activity

Table 5.2 shows the average Likert-scores for each activity at a glance. The columns show the average responses for each of the three questions. The final column classifies the activity per Table 5.1. The table is sorted in ascending order based on comfort with the material.

Figure 5.1 shows comfort by activity as pie charts. From this figure it is easy to see that the least comfortable activities during the workshop were FSA, Image Representation, and AI and the most comfortable were Searching, Binary Numbers, and Parity and Error Detection. The figure also shows that there was more variation for some activities than others.

Table 5.2: Average activity comfort levels surveyed during the workshop

Activity	Material	Usage	Logistics	Approximate Classification
Searching	4.85	4.62	4.85	Extremely High
Binary Numbers	4.75	4.83	4.67	Extremely High
Parity and Error Detection	4.58	4.75	4.83	Extremely High
Cryptography	4.58	4.5	4.42	High
MST	4.42	4.67	4.55	High
Deadlock and Routing	4.5	4.58	4.33	High
CV	4.23	4.15	4	Moderate
FSA	4.17	4.08	4	Moderate
Image Representation	4	4.08	4	Moderate
AI	4.08	4	3.5	Moderate

5.1.1.2 Results By Category

Combining the responses for each category created an overall average for each question. Although there was some variation between activities, as shown in Figure 5.1, the teachers overall had high levels of comfort with the material (4.41 average), the logistics (4.30 average) and using the lessons in the classroom (4.42 average). Figure 5.2 illustrates these results.

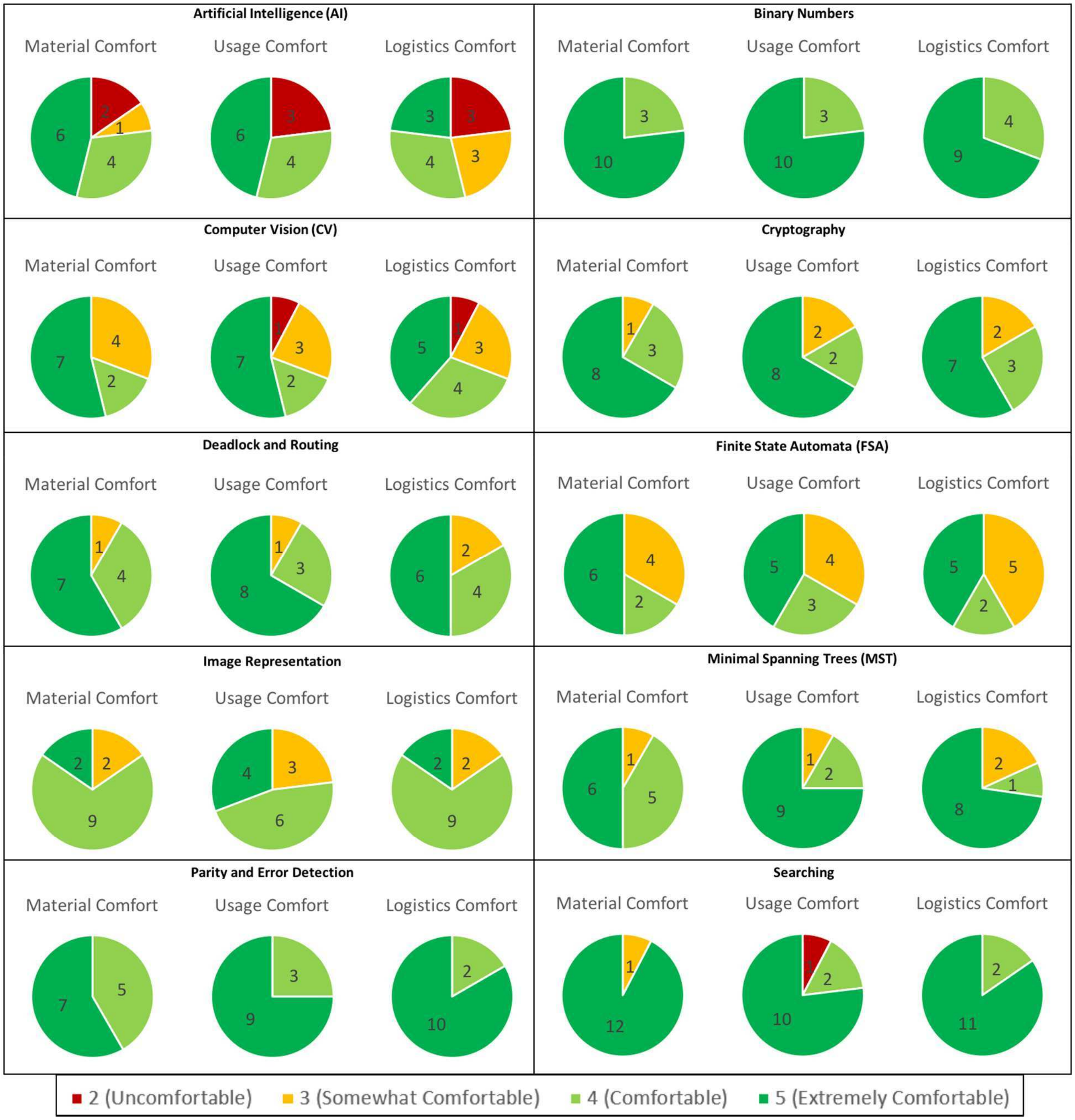


Figure 5.1: Activity comfort levels surveyed during workshop

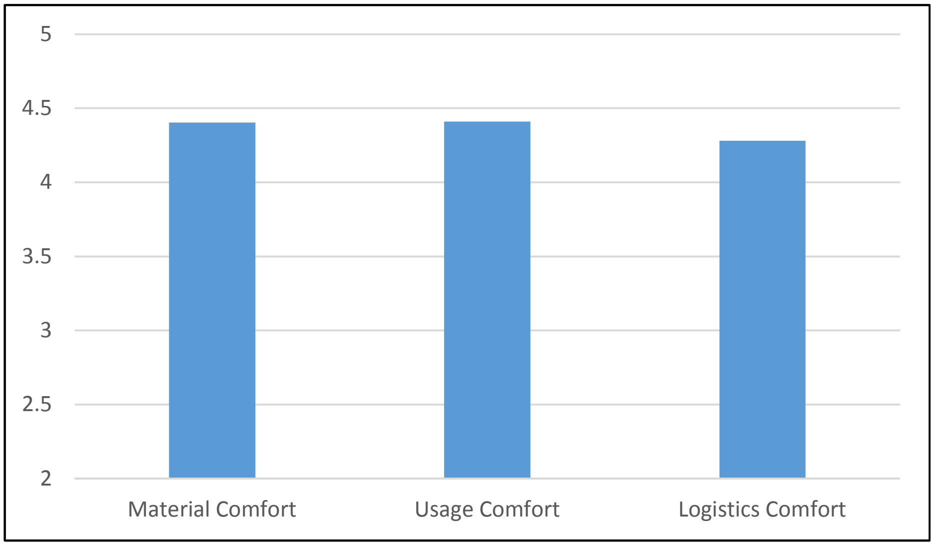


Figure 5.2: Combined average comfort level surveyed during workshop

5.1.2 Deployment Results

For each activity deployed, teachers were asked to complete a report to give feedback on their experience teaching the lesson in their classroom. The teachers were asked to respond to the questions using Likert-scale responses from 1 to 5, with the five options being “Extremely Uncomfortable” (1), “Uncomfortable” (2), “Somewhat Comfortable” (3), “Comfortable” (4), and “Extremely Comfortable” (5). The following questions from the experience reports relate to confidence/comfort:

- How comfortable were you when deploying the activity?
- How confident are you that you could accurately grade the worksheets (if any)?

The experience report did not include any open-ended questions to probe these responses. Additional feedback is discussed, however, using input from the semi-structured interviews.

5.1.2.1 Results By Activity

Table 5.3 shows the average scores for usage and grading comfort, as well as the number of teachers who deployed each activity. From the table we see that teachers were generally comfortable (average ≥ 4) deploying all activities except FSA and Deadlock and Routing; in addition, teachers were generally comfortable in grading all activities except Deadlock and Routing.

This table has one activity (Sorting) not previously listed. Two teachers who did not attend the workshop found this activity on the Unplugged website and chose to deploy it.

Table 5.3: Average activity comfort levels after deployment

Activity	***Usage Comfort***	***Grading Comfort***	***# of Teachers***	**Approximate Classification**
CV	4.5	4.83	6	Extremely High
Cryptography	4.71	4.57	7	High
Image Representation	4.25	4.85	8	High
Searching	4.5	4.5	4	High
Binary Numbers	4.15	4.77	13	High
MST	4.5	4.375	8	High
Parity and Error Detection	4	4.75	4	High
Sorting	4	4.5	2	High
AI	4	4	4	Moderate
Deadlock and Routing	3.5	3.5	2	Comfortable
FSA	3	4	1	Comfortable

Figure 5.3 shows the breakdown for usage and grading comfort for each of the individual activities. From this figure we can see that the most comfortable activities for teachers were Binary Numbers, CV, Image Representation, and MST. Cryptography is interesting in that it was rated as very comfortable by six teachers but received the only "Uncomfortable" rating of any activity. The rest of the activities have mixed results or were not deployed enough times to come to a significant conclusion (e.g., FSA).

5.1.1.2 Results By Category

As shown in Figure 5.4, teachers generally had high levels of comfort when deploying all of the Unplugged activities (4.27 average response) and were highly confident that they could grade all the worksheets (4.57 average response). None of the teachers stated that they were "Uncomfortable" or "Extremely Uncomfortable" with using the lessons in the classroom, although one teacher was "Uncomfortable" grading one of the activities.

5.2 Teacher Understanding

For instruction to be effective, teachers must understand the material. This section presents both direct and indirect measures of teacher understanding. The direct measures include assessment instruments that were scored by the researchers. Indirect measures include Likert-scale questions that were categorized by two researchers.

5.2.1 Workshop Results

To determine whether students were learning the desired concepts, the Unplugged team developed rubrics and scored worksheets completed during the activities as well as a comprehensive project completed after all activities had been deployed. That same approach was used to evaluate what teachers learned during the summer workshop.

Figure 5.3: Average deployment comfort by activity

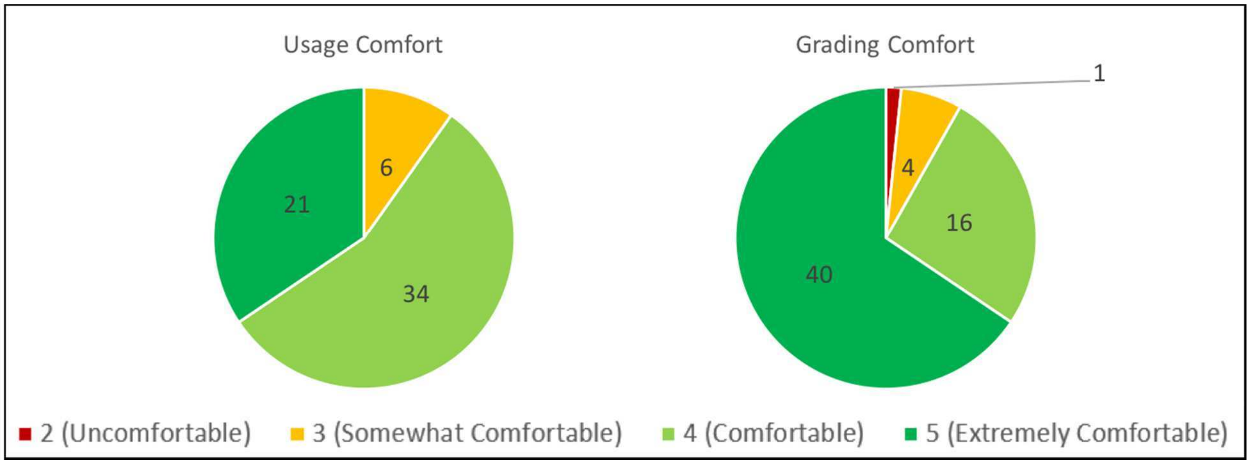


Figure 5.4: Usage and Grading Comfort Responses

Only six of the ten lessons had formal assessments: Binary Numbers, Cryptography, FSA, MST, Parity and Error Detection, and Searching. The comprehensive project covers those same topics. Teachers completed the comprehensive project at the end of the workshop. Every question on the worksheets and comprehensive project was graded as "Unsatisfactory", "Partially Proficient", or "Proficient" and was assigned a corresponding numerical value of "1", "2", or "3", respectively.

The results of the assessments are shown in the following sections. The number of teachers who completed each worksheet varies, and will therefore be reported within each section.

5.2.1.1 Binary Numbers Activity Assessment Results

The Binary Number activity assessment (Appendix I) had six questions that assessed student understanding:

- *"What is the next number in the sequence?"* - (Q1)
- *"What decimal number is represented by 01011?"* - (Q2)
- *"How would you write the number 20 in binary?"* - (Q3)

- *"What is the largest number you can represent using five cards (i.e., five bits)?"* - (Q4)
- *"What is the largest number you could represent if you had only three cards?"* - (Q5)
- *"How many cards (bits) would you need to represent the number 63?"* - (Q6)

These questions were scored according to the Binary Number rubric (Appendix J). Thirteen teachers completed this worksheet. The results for each question are illustrated in Figure 5.5.

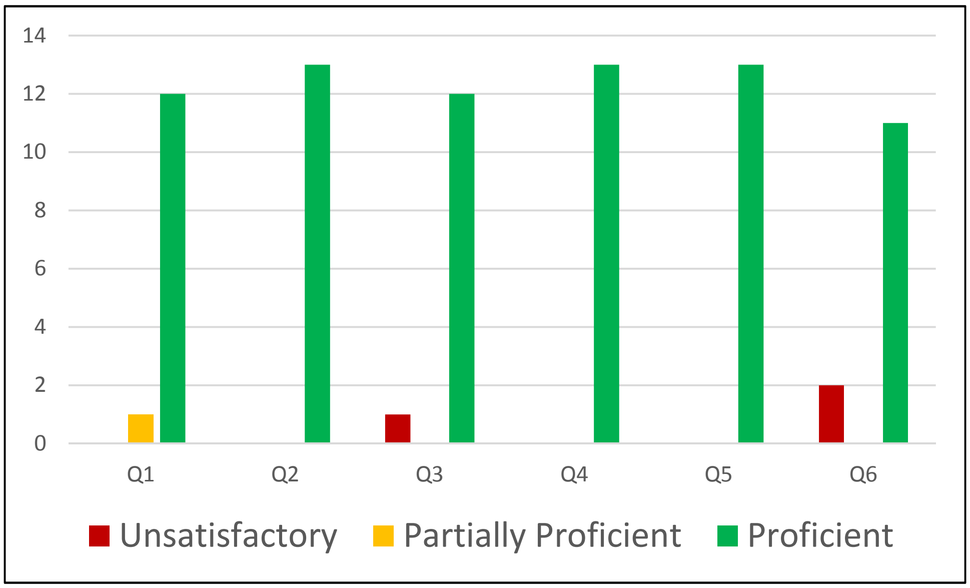


Figure 5.5: Binary Numbers assessment scores

All 13 of the teachers were able to:

- Convert a binary number to decimal. (Q2)
- Correctly identify the largest number that could be represented with a fixed set of cards (i.e., number of bits). (Q4, Q5)

Q1 gives the sequence "0001 0010 0011 0100" and asks for the next number in the sequence. All but one of the teachers provided the correct answer (0101). The teacher who did not correctly complete the pattern wrote down "0100" as the continuation of the series. During the activity, students use flip cards to count. In the classroom this typically takes about 10 minutes, but in the workshop only one repetition was done. Perhaps this teacher needed another repetition to fully understand the pattern. Or perhaps this was a careless mistake, since the teacher's answer simply repeated the last number in the sequence.

All but one of the teachers correctly converted the number 20 into binary (Q3). This teacher was not the same teacher who answered Q1 incorrectly.

Q6 is the most abstract question on this assessment, as it requires an understanding of both binary number representation and the process for determining how many bits are required for a given number. Most of the teachers correctly identified the number of bits needed, but two of the teachers gave answers that deviated greatly from the correct answer and were scored as "Unsatisfactory."

5.2.1.2 Cryptography Activity Assessment Results

The Cryptography activity assessment (Appendix K) had three sections that assessed student understanding of the various facets of the Caesar cipher:

- Encryption – *"Complete the table below to show what each letter is enciphered using this system."*
- Analysis – *"Computer scientists would call 3 the 'key' for this cipher. How many different keys are possible?"*
- Decryption – *"Decode this message, which was encoded using the Caesar cipher from the table above."*

These questions were scored according to the Cryptography rubric (Appendix L). Ten teachers completed this worksheet. The results for each question are illustrated in Figure 5.6. In short, all ten teachers were scored proficient on the cryptography assessment.

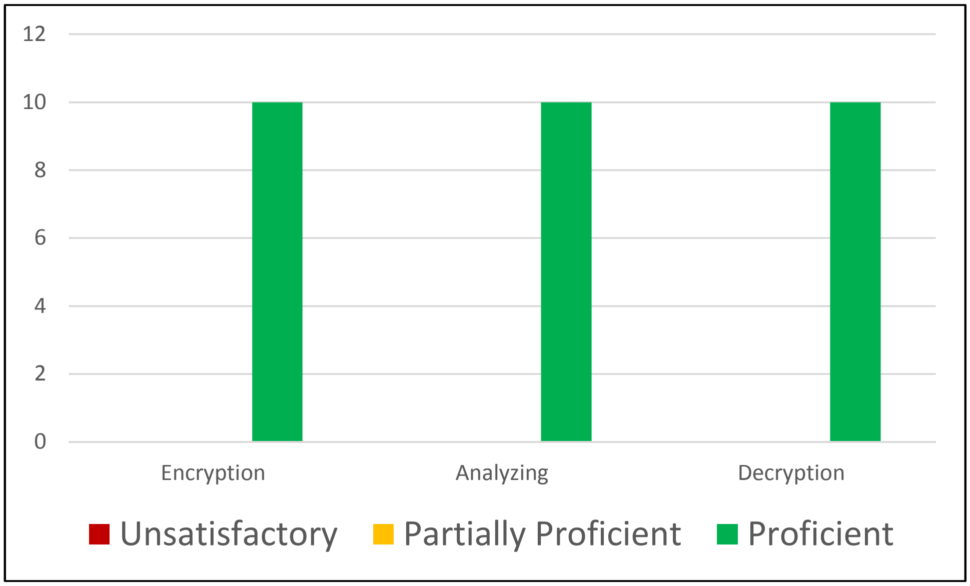


Figure 5.6: Cryptography assessment scores

5.2.1.3 FSA Activity Assessment Results

The FSA activity assessment had five questions that assessed student understanding of the various facets of FSA. The questions were distributed through two worksheets, the “Robot Dog” worksheet (Appendix M) and the “Chores Robot” worksheet (Appendix N).

The “Robot Dog” worksheet was comprised of three questions focused on understanding the mechanics of an existing FSA, including:

- State identification – *“Identify the following states (Start State and Stop State).”*
- Transitions between states – *“Identify what the dog will be doing after each set of actions or write **ERROR** if the set of actions is not valid.”*
- State selection – *“Circle the paths from question 2 where the dog barks.”*

The “Chores Robot” worksheet was comprised of two questions focused on understanding the mechanics of creating a new FSA, including:

- Construction– *“Use the instructions to create an FSA for your robot”*
- Transitions between states – *“What sequence of button pushes will get your robot to do all of your chores?”*

These questions were scored according to the FSA rubric (Appendix O). Ten teachers completed the worksheet. The results for each question are illustrated in Figure 5.7.

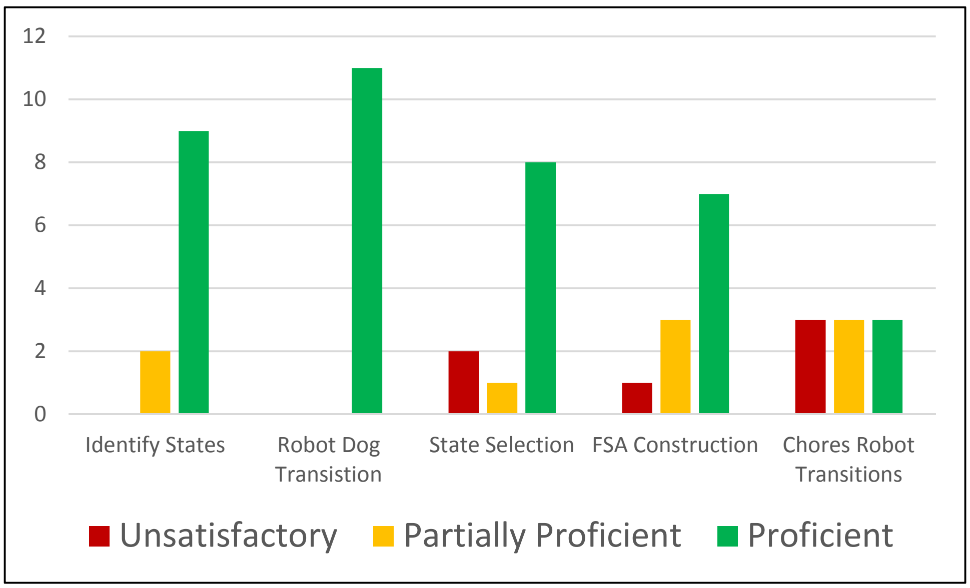


Figure 5.7: FSA assessment scores

For the Robot Dog worksheet, all of the teachers were able to identify valid transitions, and most were able to identify key states in the FSA. We believe the lower result in identifying states stems from an issue in the introductory lecture. Specifically, not much time was devoted to teaching about states with special functions; thus, two teachers did not correctly identify the “stop” state in the diagram. The teachers were slightly less successful at selecting paths where a given event happens in the FSA, but this result is attributable to the fact that two of the teachers did not realize that there was a third question on the worksheet (and thus received an “Unsatisfactory” score).

On the Chores Robot worksheet, teachers were moderately proficient at constructing an FSA from a set of requirements. The two teachers who scored “Partially Proficient” did not provide a FSA from the requirements given (i.e., they incorrectly created transitions between states). One of the teachers did not use any of the diagraming techniques shown in the lecture, which led to the lone “Unsatisfactory Score”. The teachers did not do well on the “Chores Robot” transition identification question (only three teachers were scored as “Proficient”). This result may not reflect teacher understanding, however, as this activity was cut short in order to move on to the next subject scheduled in the workshop. Since teachers were generally able to identify transitions on the “Robot Dog” worksheet, it seems likely that teachers understood the core concept of identifying transitions between states.

5.2.1.4 Searching Assessment Results

The Searching activity assessment (Appendix T) included one question that was scored according its corresponding rubric (Appendix U). Twelve teachers completed this worksheet. This worksheet required teachers to use a binary search to find a hidden object. The worksheet is structured so that two teachers work together. The results are illustrated in Figure 5.8.

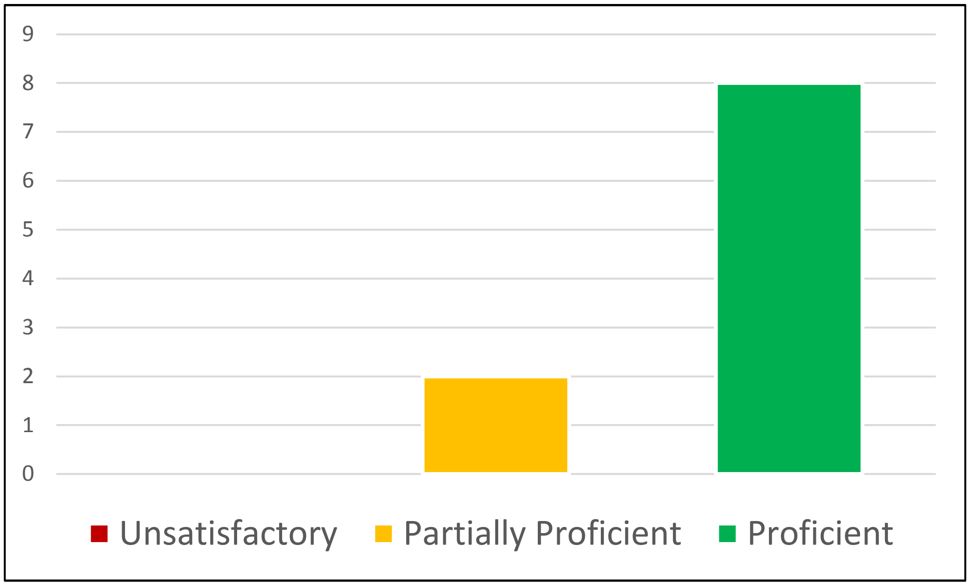


Figure 5.8: Searching assessment scores

Most of the teachers were able to correctly use the “Binary Search” algorithm to complete the assignment. Unfortunately, two teachers neglected to turn in the worksheets. Two other teachers made logical guesses in order to solve the problem, but did not use the specific algorithm taught in the lecture.

5.2.1.5 MST Assessment Results

The MST activity assessment (Appendix P) contained just one question that was scored according to its corresponding rubric (Appendix Q). Twelve teachers completed this worksheet. This worksheet presented a weighted graph to the teachers and asked them to construct the MST of the graph. The worksheets were evaluated on the correctness of the resulting MST. The results for this question are illustrated in Figure 5.9.

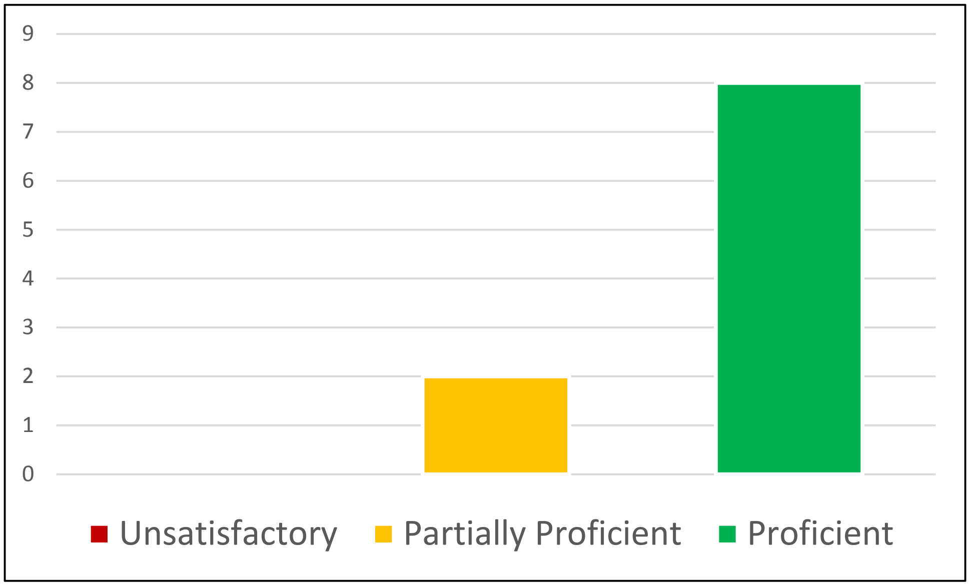


Figure 5.9: MST assessment scores

Most of the teachers correctly used the algorithm demonstrated in class to construct the MST for the graph given. Two teachers were not able to identify the minimal solution because some unnecessary paths between nodes were not eliminated. Unfortunately, two teachers neglected to turn in their worksheets.

5.2.1.6 Parity and Error Detection Assessment Results

The Parity and Error Detection activity assessment (Appendix R) had three questions that assessed student understanding:

- Data Representation – "*Translate this message from binary numbers to English letters*"
- Parity Bits – *"Complete the table by filling in the parity bit for the letters W,X,Y and Z."*
- Error Detection – *"Is there an error in the message?"*

These questions were scored according the Parity and Error Detection rubric (Appendix S). Twelve teachers completed this worksheet. The results for each question are illustrated in Figure 5.10.

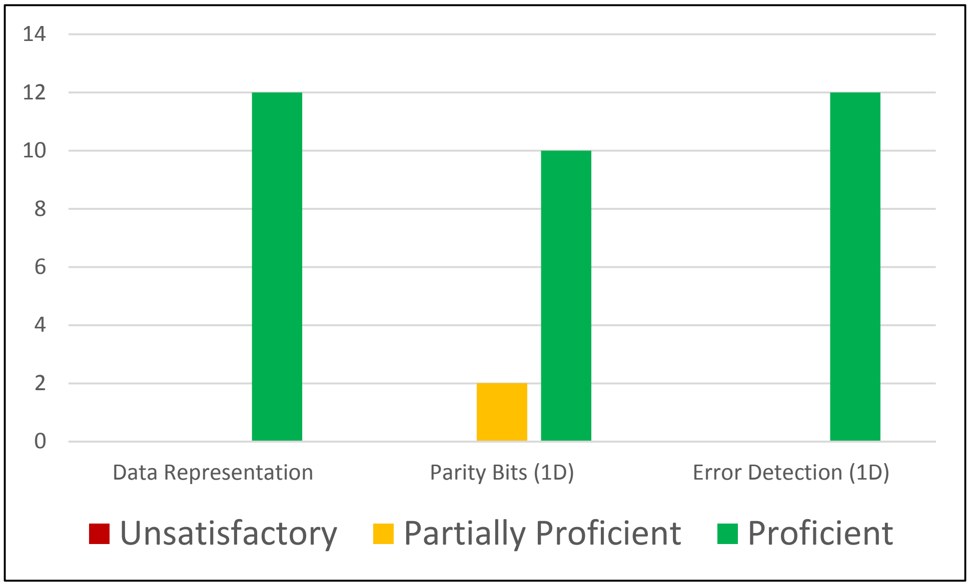


Figure 5.10: Parity and Error Detection assessment scores

All of the teachers were “Proficient” at representing data and detecting errors in a message. Most of the teachers were able to determine parity bits for letters, though two teachers left this section of the worksheet blank. It is not clear whether they overlooked the question or were not sure how to answer; thus, we scored them as “Partially Proficient”.

5.2.1.7 Final Project Results

The final project (Appendix E) assessed teacher understanding of Binary Numbers, Cryptography, FSA, MST, and Searching. The final project asked the following questions:

- *“Connect all of the cities using the smallest amount of cash.”* – (MST)
- *“Work on a solution to this problem by organizing the states and transitions.”* – (FSA Q1)

- *“Circle any of the following schedules if they follow the teller’s rules, starting from the sleeping state.”* – (FSA Q2)
- *“The number system Sammy uses only has 1’s and 0’s: Can you decode the following message from Sammy?”* – (Binary Decoding/Cryptography)
- *“If Odin wants to read a book, he has to search through his library to find it (assume he knows the title of the book). How many items does Odin have to look at in order to find what he is looking for?”* – (Searching)
- *“The culprits hide in different spots depending on their favorite number, so you’ve recorded each of their favorite numbers and you are now put in charge of assisting the police in apprehending the suspects”* – (Optional Binary Numbers Question)

The final projects were scored according to the corresponding rubric (Appendix V). Twelve teachers completed the final project. Results are shown in Figure 5.11.

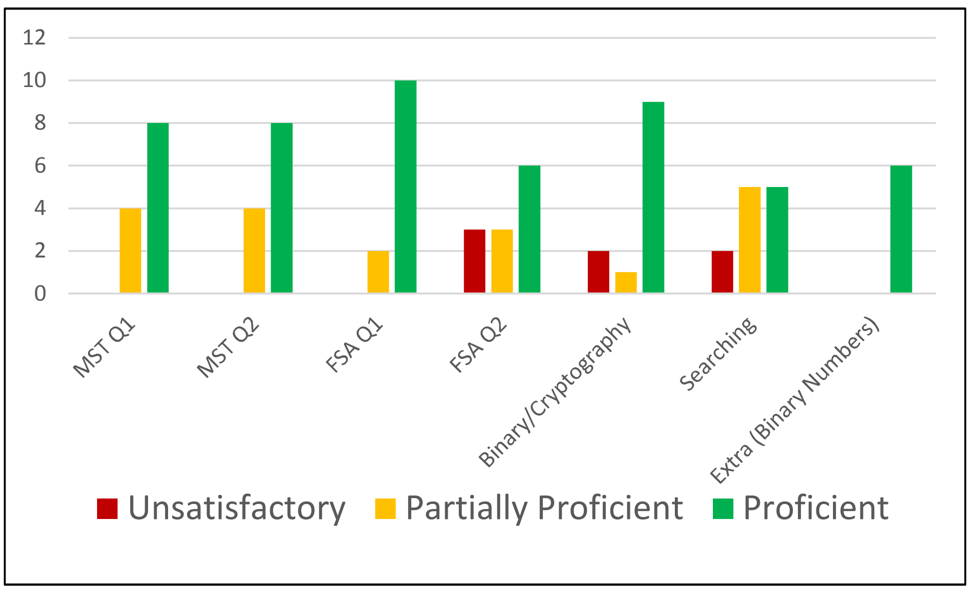


Figure 5.11: Final Project Assessment Scores

MST: The eight teachers who successfully completed the MST worksheet were able to replicate their success on the final project. The teachers who did not construct the correct MST failed to eliminate enough edges to create the minimal tree. It is likely that these four teachers do not understand Kruskal's algorithm well enough to teach this activity.

FSA Q1: For the first FSA question, teachers were presented with a list of states and events and asked to organize the list. To avoid biasing the result, the instructions did not explicitly state that an FSA should be created. The ten teachers marked as "Proficient" for this task recognized that an FSA was appropriate and created a complete FSA. The two teachers marked as "Partially Proficient" for this task created an FSA but failed to include all of the transitions between states.

FSA Q2: The second FSA question presented three columns with possible schedules for the fortune telling robot, of which two were valid. This question corresponds closely to the State Selection (Robot Dog) and Chores Robot Transitions. A prerequisite for this question is to have a valid FSA, so it is unlikely that teachers who did not generate a correct FSA in Q1 would be able to answer this question successfully. Although ten teachers generated the FSA in Q1, only six were able to identify the valid schedules from the options presented in Q2. Three teachers identified one of the correct schedules, but not both. The three remaining teachers appeared to be confused by the format of the question, as they incorrectly circled rows instead of columns.

Decoding: The binary decoding question required teachers to convert a number from binary to decimal and then use the decimal number to look up the corresponding character (e.g., 00001 in binary is 1 in decimal and corresponds to the letter 'A'). Most of the teachers (9) were scored as "Proficient" in this task. One of the teachers partially converted the message from binary; this teacher did not properly convert one of the letters. Two teachers did not properly convert from binary to decimal using the conversion method taught in the lecture. Both errors stemmed from a common misconception that each bit adds 2 to the result, instead of multiplying by 2 (e.g., while 1000 represents 8, these teachers converted 1000 to 6).

Search: Only five of the teachers were able to correctly determine the guaranteed maximum number of steps needed to find the desired object by using the Binary Search algorithm. Two of the teachers gave answers that came as a result of not applying any algorithm to the problem. One teacher left this question blank.

Binary Numbers: All of the teachers that attempted the extra credit Binary Numbers question correctly answered the problem. Six teachers chose not to attempt this question.

5.2.1.8 Summary of Results

For each activity, all of the worksheets were collected and scored according to the corresponding rubrics. These scores were assigned a numerical value, with “1” representing “Unsatisfactory”, “2” representing “Partially Proficient”, and “3” representing “Proficient”. These scores were then averaged to derive a score for the overall activity. For activities with just one question (MST and Searching), this average matches the previously reported result. The average results for each activity are shown in Figure 5.12.

Overall, the teachers were highly proficient on the in-activity assessments, as the average for all activities was above 2.5 (which is between “Proficient” and “Partially Proficient”). Based on Figure 5.12, it appears:

- All teachers understood the material from Binary Numbers, Cryptography, and Parity and Error Detection well enough to deploy these activities.
- Most teachers understood MST and Searching well enough to deploy, although a few teachers did not master the material.
- Few teachers mastered the FSA material, perhaps due to a shortened lecture time and a complex kinesthetic activity.

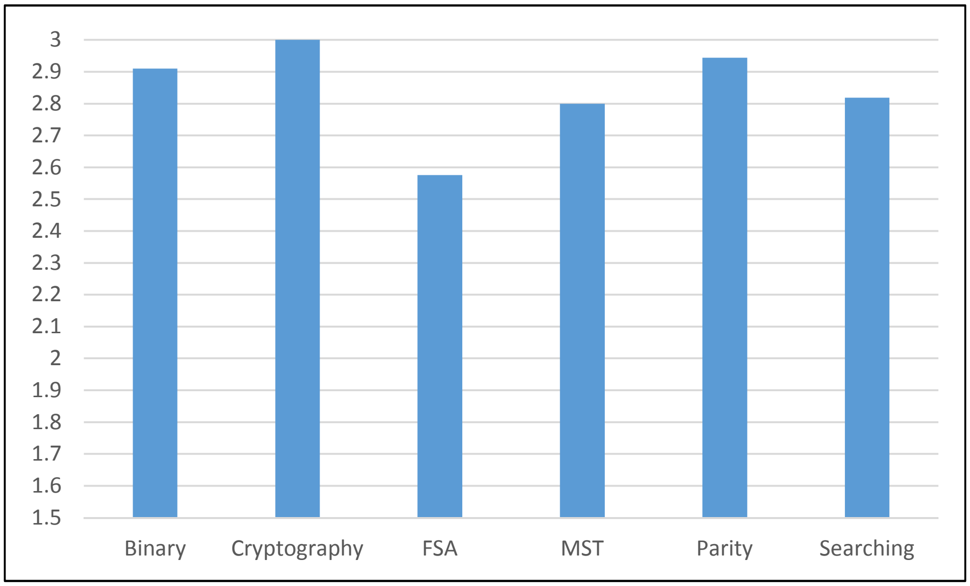


Figure 5.12: Average workshop activity scores

5.2.2 Deployment Results

In order for teachers to use the material in their classrooms, they must understand the material well enough to deliver the introductory lecture, explain and assist with the hands-on activities, and answer any questions that students might ask. This section reports teachers' assessments of their own understanding.

For each activity teachers deployed, they were asked to complete a report to give feedback on their experience teaching the lesson in their classroom. The following question from the experience reports was asked in order to assess material comprehension:

- How would you rate your understanding of the material when presenting it to your class(es)?

The teachers were asked to respond to the questions using Likert-scale responses from 1 to 5, with the five options being "Extremely Weak" (1), "Weak" (2), "Somewhat Strong" (3), "Strong" (4), and "Extremely Strong" (5). Figure 5.13 shows the results by activity.

All teachers ranked their understanding as strong (either 4 or 5) for Binary Numbers, Computer Vision, Cryptography, FSA, MST, Searching, and Sorting. Most teachers believed they had a strong understanding of AI and Image Representation, although one teacher indicated only moderate understanding in each case. Deadlock and Routing and Parity and Error Detection had the weakest results. For Deadlock and Routing, only two teachers chose to deploy that activity and both indicated a somewhat strong level of understanding. The results for Parity and Error Detection were mixed, with two teachers indicating they did understand the material and two indicating they did not. Table 5.4 demonstrates the categorization of comfort levels.

Table 5.4: Average understanding levels after deployment

Activity	***Understanding***	***# of Teachers***	**Approximate Classification**
Cryptography	4.71	7	High
CV	4.5	6	High
Binary Numbers	4.38	13	High
Image Representation	4.25	8	High
Searching	4.25	4	High
MST	4.25	8	High
Sorting	4	2	Moderate
AI	4	4	Moderate
Parity and Error Detection	3.5	4	Comfortable
Deadlock and Routing	3	2	Comfortable
FSA	3	1	Comfortable

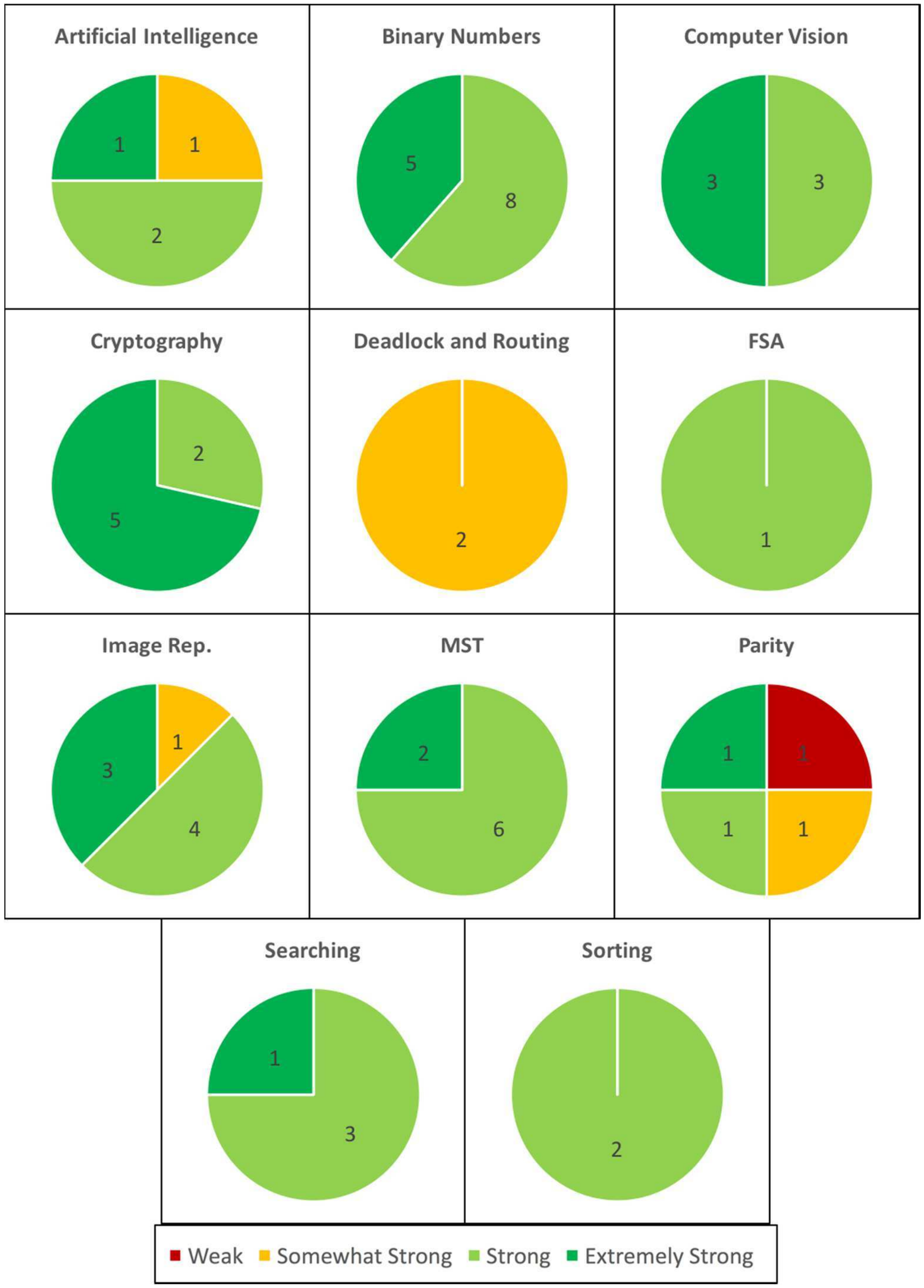


Figure 5.13: Deployment understanding results

As shown in Figure 5.14, most teachers believed they had a “Strong” or “Extremely Strong” understanding of the material (54/61 responses, 88%).

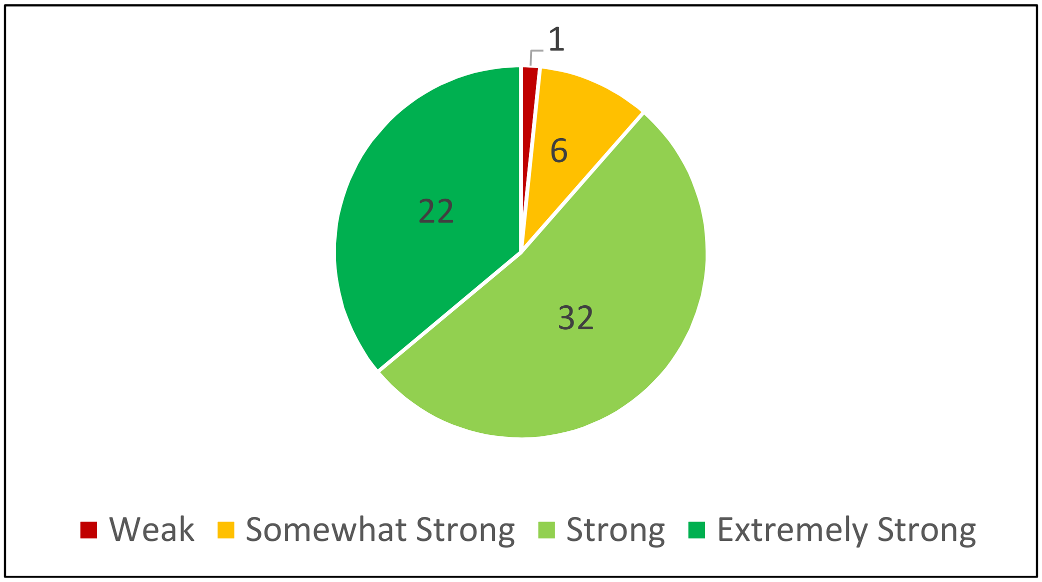


Figure 5.14: Total responses related to understanding

5.2.3 Experience Report Free Response Question

The teachers were asked to respond to the following question to gain more insight into how they rated their understanding of the material:

- *Do you think you would benefit from more instruction on the CS concepts this activity covered? Why or why not?*

Although the goal of this question was to assess teachers’ level of understanding, the responses did not easily fit into a simple yes/no classification. The following categories emerged from the data:

Teachers who do want more instruction

- **Yes**. These responses indicated teachers wanted more information in order to be comfortable with existing lesson.

- **Maybe**. Some teachers indicated a general desire for more information, but did not seem to indicate they had issues with the existing lessons.
- **Reinforce**. Some teachers sometimes understood the activity, but wanted additional material to reinforce the topic.
- **Extend**. Some teachers sometimes wanted additional material to expand the activity.

Teachers who do not want more instruction

- **Level**. Material is appropriate depth for middle school; more instruction is not needed.
- **Understand**. Some teachers felt they understood the concepts and did not need more instruction.
- **No.** Several teachers indicated no more instruction was needed.

A few responses did not fall into any category and were coded as "Other." From the results gathered, it appears that, overall, teachers feel as if they would benefit from additional instruction. Table 5.4 shows the categorized responses for each activity and a total for each category.

Table 5.5: Categorized understanding free responses by activity

Categories	AI	Binary	CV	Crypto	Deadlock	FSA	Image Rep	MST	Parity	Searching	Sorting	Total
Yes	2	3	1		2			1	2		1	12
Maybe		2	1	1				3				7
Reinforce		1	1				2	1				5
Extend		2	1	2		1	4	2	1	1		14
Level	1	2	1	1							1	6
Understand		1										1
No		2	1	3			3		2	3		14
Other	1						1			1		3

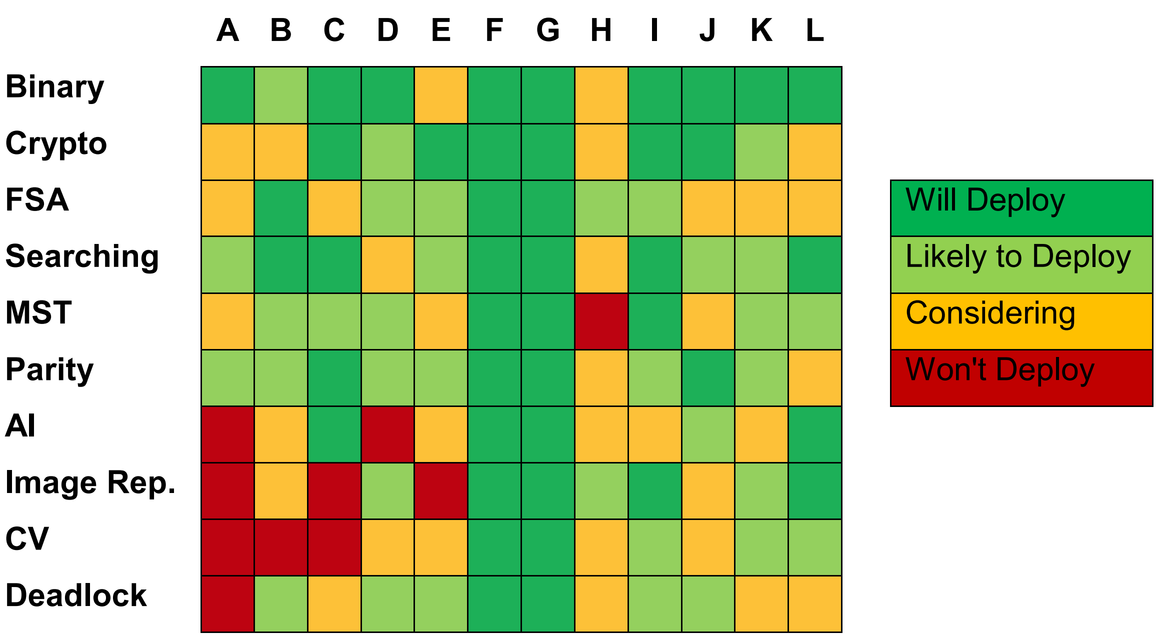
5.3 Teacher Usage

Teachers were asked whether they would actually deploy CS Unplugged in their classrooms. This section presents their intentions, as indicated during the summer workshop, and the results from the deployments during fall semester 2016.

5.3.1 Workshop Results

In the Workshop Survey, 12 teachers were asked to rate their likelihood of deploying the individual activities. Their responses are reflected in Table 5.5. The letters correspond to the individual teachers who attended the workshop.

Table 5.6: Workshop deployment intentions



The maximum number of activities that could be deployed is 120 (12 teachers deploying 10 activities each). Teachers selected “Will Deploy” or “Likely to Deploy” for 77 (64.2%) of the activities. Teachers were considering another 33 (27.5%) activities. Only 10 activities (8.3%) were rated as “Will Not Deploy”. Eleven out of 12 teachers rated at least one activity as “Will Deploy”.

For the activities that teachers stated they would not deploy, it is important to understand the reasoning. Figure 5.15 shows the reason for the “Will Not Deploy” responses given on the Workshop Survey.

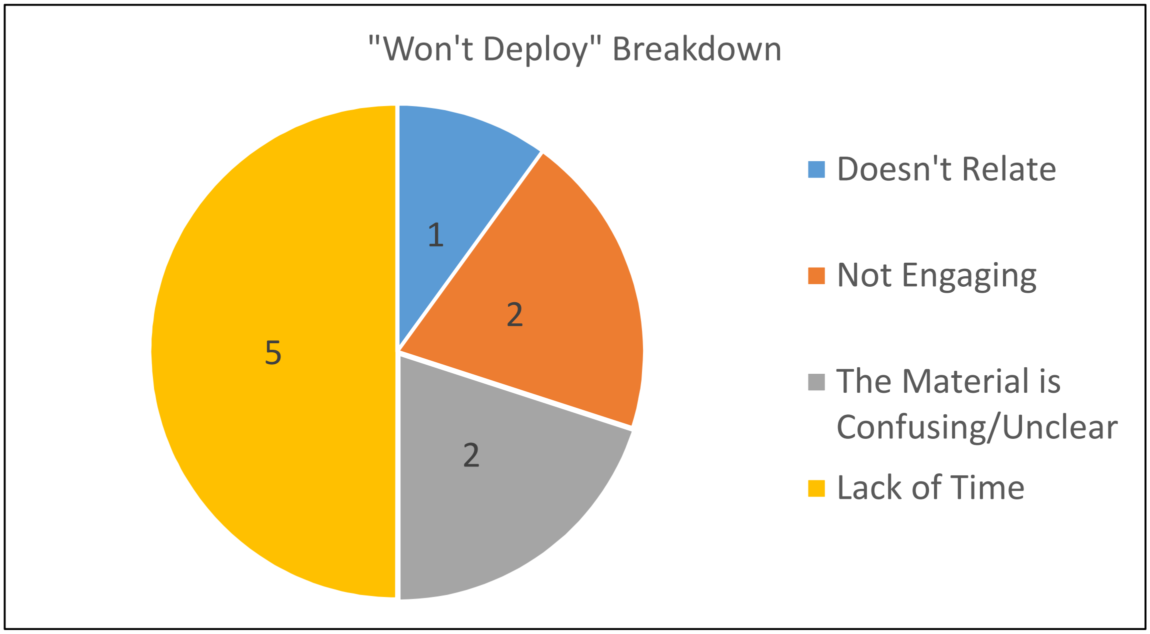


Figure 5.15: Distribution of “Won’t Deploy” responses

Lastly, Table 5.6 shows the distribution of the “Would Not Deploy” responses among the activities.

Table 5.7: “Will Not Deploy” Workshop distributions

Doesn’t Relate	**Not Engaging**	**Material is Unclear**	**Lack of Time**
CV (1)	AI (1)	Image Rep. (2)	AI (1)
	CV (1)		CV (1)
			Deadlock and Routing (1)
			Image Rep (1)
			MST (1)

5.3.2 Deployment Results

In total, 14 teachers deployed one or more of the Unplugged activities before our deadline (Oct. 1st, 2016). Of the 13 teachers that attended the summer workshop, 10 teachers taught one or more Unplugged lessons. Two of the teachers (labeled “B” and “H” in Table 5.5) indicated they were not teaching CS courses in the fall of 2016, but planned to use the material learned in future semesters. In total, 61 Experience Reports were submitted by teachers. Table 5.8 shows the number of deployments for each activity during the reporting window.

Table 5.8: Deployment distributions

Activity	# of Deployments
Binary Numbers	13
Image Representation	10
Minimal Spanning Trees (MST)	8
Cryptography	7
Computer Vision (CV)	6
Artificial Intelligence (AI)	4
Parity and Error Detection	4
Searching	4
Deadlock and Routing	2
Sorting	2
Finite State Automata (FSA)	1

The following open-ended questions related to usage were asked on the Experience Report:

- *(Q13) Do you plan to use this activity again? Why or why not?*
- *(Q15) Did you modify the activity in some way to fit your course?*
- *(Q16) Did you encounter any difficulties?*

The following subsections report the results for these three questions.

Do you plan to use this activity again? Why or why not?

This question addresses whether teachers will use CS Unplugged in their classrooms. Teacher responses were categorized as “Yes”, “No”, or “Maybe”. Table 5.9 displays the categorized totals for each activity. For 6 of the 10 activities, all teachers who taught the activity are planning to do so again. This is an encouraging result.

Table 5.9: Distribution of categorized responses to “Do You Plan to Use Again?” by activity

Category	**AI**	**Binary**	**CV**	**Crypto**	**Deadlock**	**FSA**	**Image Rep.**	**MST**	**Parity**	**Searching**	**Sorting**	**Total**
Yes	2	13	5	7	2	1	8	8	5	4	2	57
Maybe	2		1				1					4
No							1			1		2

To help identify factors that encourage or discourage usage, teachers were asked to elaborate on why they would/would not deploy again. The responses were categorized as Positive or Negative, with various subcategories relating to different facets of teachers’ experiences. The following categories were identified:

Positive categories: Activity Structure, Engaging, Relates to Computing, Relates to Other, None/General, Problem Solving, Teacher Comfort.

Negative categories: Activity Issue, Not Engaging, Hard Concept, Didn’t Fit.

Example responses from each category are shown in Table 5.10. Positive categories are highlighted in bold.

Table 5.10: Sample categorized responses to “Do You Plan to Use Again?”

Category	Examples
Activity Structure	Yes, very well laid out & easy to follow.
Engaging	Yes because the kids really enjoyed it.
Relates to Computing	I would use this again because I believe it's important for students to see a visualization of the picture and how that translates to data.
Relates to Other	Yes. Place value is a foundational topic in math, the use of a base 2 system to better understands the base 10 system is well worth the time.
None/General	Yes, this was a great intro to binary.
Problem Solving	Yes, because I really like emphasizing the problem solving aspect of the activity.
Teacher Comfort	Yes, I felt fairly confident presenting the activity and I think it is a great introduction to how computers process information.
Activity Issue	No I wouldn't. I did not think this lesson did a very good job connecting how computers search for items compared to this lesson.
Not Engaging	It wasn't as engaging as the other ones.
Hard Concept	I would use this activity again. However, this concept was difficult for some students.
Didn’t Fit	No, it didn't quite fit the way I had hoped.

Table 5.11 shows the number of responses of each type per each activity.

Table 5.11: Sample categorized responses to “Do You Plan to Use Again?”

	AI	Binary	CV	Crypto	Deadlock	FSA	Image Rep.	MST	Parity	Searching	Sorting	Total
Activity Structure		2	1				1	1				5
Engaging	1	4	2	3			4	3	2	1		20
Relates to Computing	1	4	4	1	1	1	3	1	1	1		18
Relates to Other		2		1				1		1	1	6
None/General		3		2					1			6
Problem Solving		1		1				3				5
Teacher Comfort		1			1							2
Activity Issue	1									1		2
Not Engaging	1											1
Hard Concept							1		1			2
Didn't Fit							1					1

Did you modify the activity in some way to fit your course?

This question does not directly answer whether teachers will use CS Unplugged in their classrooms, but does provide additional context to reasons that teachers may or may not redeploy an activity. Teacher responses were categorized as “Yes”, “Slight Modification”, “Added Material”, “Timing Issue”, “Removed Worksheet/Activity”, and “No”. Table 5.12 displays the categorized totals for each activity.

Did you encounter any difficulties?

This question also provides indirect feedback that relates to whether teachers will continue to use CS Unplugged in their classrooms. The categories that emerged can again be classified as positive (no difficulties) or negative (explanation of difficulties).

Table 5.12: Distribution of categorized responses to “Did you modify the activity?”

Category	AI	Binary	CV	Crypto	Deadlock	FSA	Image Rep.	MST	Parity	Searching	Sorting	Total
Yes		1										1
Slight Modification	1	4	3	2	1		2	3		1	1	18
Added Material		3		1	1							5
Timing Issue			1					3		2		6
Removed Worksheet/Activity		1					1		1			3
No	3	4	2	4	3	1	7	2	1	2	1	30

Teachers who did not encounter difficulties

- **No**. These responses indicated that the teachers had no difficulty teaching the lesson.
- **Easy**. These responses indicated that the teachers had no difficulty teaching the lesson, but that the content may have been too easy for the class.

Teachers who encountered difficulties

- **Timing**. These responses indicated that the teachers felt as if they ran out of time to properly go through all of the material in a single class period or that the material in the activity did not fill enough time.
- **Confusion**. These responses indicated that the teachers felt that the students were confused about the material being taught.
- **Worksheet(s)**. These responses indicated that the teachers felt the students struggled with the worksheet(s).
- **Logistics**. These responses indicated that the teachers had difficulties with the logistics of teaching the material.
- **Materials**. These responses indicated that the teachers had issues with the online materials provided.
- **Hard**. These responses indicated that the teachers felt the students had a hard time grasping the material or working through the activities.

Examples responses from each category are shown in Table 5.13. Positive categories are displayed in bold.

Table 5.13: Sample categorized responses to “Did you encounter any difficulties?”

Category	Examples
No	No, I didn't. Students really got an understanding of it.
Easy	I think for 8th graders, it went fairly quickly.
Timing	I didn't have enough time to [complete](sic) the assessment.
Confusion	Students were confused with the raffle assignment and who was reading what. I just needed to explain it better.
Worksheet	The worksheet was intimidating for the kids. Although it wasn't that much actual work, the kids looked at the sheet in horror.
Logistics	Students mixed up my decks of binary cards so next time I will color code the decks.
Materials	The Powerpoint didn't include the same grid as the worksheets, so it was difficult to demonstrate that.
Hard	A few groups struggled with figuring out the fickle fruit process, but the robot chores was much smoother. They did learn as the activities developed.

Table 5.14 shows the distribution of the responses for each activity.

5.4 Additional Data

We also collected data that does not directly relate to the three research questions. This extra data can help us provide additional context for the results gathered from the teachers.

Table 5.14: Distribution of categorized responses to “Did you encounter any difficulties?” by activity

Category	AI	Binary	CV	Crypto	Deadlock	FSA	Image Rep.	MST	Parity	Searching	Sorting	Total
No	3	4	4	5	1		5	6	2	2	2	34
Easy		1										1
Timing	1	1										2
Confusion		2			1		2	1		1		7
Worksheet		1							1	1		3
Logistics		2										2
Materials			1	1			1					3
Hard		2				1			2	1		6
Other				1			2	1				3

5.4.1 Workshop Free Response Results

On every activity survey, the teachers were asked the following question:

- *How could we modify this activity to be more engaging, relevant, or easy to deploy?*

From these responses, we created a to-do list for future iterations of the Unplugged material, which can be found in Appendix W.

5.4.2 Semi-Structured Deployment Interview Results

After the deployment window had closed, the teachers that deployed activities were interviewed about their experiences teaching CS Unplugged. Each of the teachers answered the following core questions:

- Overall, did you feel that CS Unplugged was a good use of your class time?
- Overall, did you feel that your class learned from these activities?

- Do you think that the students learned what you intended to teach from these activity?
- Did you feel that the current available resources supported your teaching?
- Were these activities easy to deploy?
- How prepared did you feel to teach these activities?
- Did you feel that the kids enjoyed the activities?
- What student questions, if any, were hard for you to answer?

In addition to the structured questions, the teachers were asked to elaborate upon their responses which led to free-form discussion that did not answer any particular question.

Of the 13 teachers surveyed, all of them had similar responses to the structured questions. In general, their answers did not deviate from the responses they gave in the experience report submissions. The teachers felt that, overall, CS Unplugged was a good use of their class time and that the students learned from the activities. The teachers also felt comfortable with the CS Unplugged lesson plans and using them in class, but cited concerns or difficulties that were already captured in the experience reports.

Through these discussions, we learned the reasoning behind the teachers' decisions regarding which activities to deploy. Several considerations were identified. Some teachers integrated the Unplugged lessons into their existing curriculum and chose lessons that would enhance their current plans. Other teachers looked at potential student engagement in order to select the Unplugged lesson plans. Many of the teachers selected material based on their level of comfort with the material and content.

When asked about the impact of the workshop, the teachers who attended the workshop thought that deploying the activities would be quite hard without receiving any training. The teachers that deployed the activities without attending the workshop agreed that the workshop might enhance their teaching, but felt the lessons could be deployed with only the materials and support found on the website.

Ultimately, all of the teachers stated that they would be using materials from the Unplugged curriculum again. Many teachers have also recommended the material to fellow teachers and/or standards boards.

CHAPTER 6: ANALYSIS

The purpose of this section is to identify and extrapolate upon points of interest among the data collected. Section 6.1 categorizes the activity into three tiers. Sections 6.2-6.12 analyze the results per activity and are roughly ordered from the most to least successful activity based on the number of deployments. Section 6.13 analyzes results for the research as a whole. All proposed curriculum changes are listed in Appendix W.

6.1 Activity Tiers

After analyzing the workshop and deployment results, it became apparent that teachers who had no prior knowledge of the CS Unplugged curriculum may be tempted to use an unpolished activity in their class and then become unnecessarily frustrated with the content. Thus, it is important to define development tiers that the activities can be sorted into; the goal is to communicate to teachers the state of classroom readiness for each activity. The 11 Unplugged activities can be organized into three tiers of completeness: Tier 1 (Polished) Activities, Tier 2 (Functional) Activities, and Tier 3 (Experimental) Activities. The categorizations are based on the activity's workshop comfort levels (Table 5.2), deployment comfort levels (Table 5.3), deployment understanding levels (Table 5.4), and number of deployments (Table 5.8). Sections 6.1.1-6.1.3 will discuss the characteristics of each tier and list the activities included within.

6.1.1 Tier 1 (Polished) Activities

Polished activities are activities that had high deployment rates, high comfort levels during the workshop and deployments, and high understanding levels during deployments. Four of the 11 activities are in Tier 1: Binary Numbers, Image Representation, Minimal Spanning Tress, and Cryptography. As shown in Table 6.1, these activities were deployed the most out of all the activities and teachers generally reported high levels of comfort and understanding. During the workshop, all teachers performed well on the Binary Numbers and Cryptography assessments. Furthermore, most teachers performed well on the Minimal Spanning Tree assessment. (We note the Image Representation activity has no assessment.) In addition, most teachers who used these activities plan to use them again.

Table 6.1: List of Tier 1 Activities

Activity	Workshop Comfort	Deployment Comfort	Deployment Understanding	# of Deployments
Binary Numbers	Extremely High	High	High	13
Image Representation	Moderate	High	High	10
MST	High	High	High	8
Cryptography	High	High	High	7

6.1.2 Tier 2 (Functional) Activities

Functional activities are activities that had somewhat high deployment rates, somewhat high comfort levels during the workshop and deployments, and high understanding levels during deployments. The activities categorized in Tier 2, and listed in Table 6.2, were selected for deployment by less than 50% of the teachers. This indicates that although the teachers who deployed the activities were comfortable and understood the material, there may have been an additional barrier to teachers choosing to deploy the activity. Furthermore, there may be bias in the deployment understanding results, as neither of the activities have assessments. Of the teachers who deployed these activities, about 90% plan to use the activities again.

Table 6.2: List of Tier 2 Activities

Activity	Workshop Comfort	Deployment Comfort	Deployment Understanding	# of Deployments
Computer Vision	Moderate	Extremely High	High	6
Searching	Extremely High	High	High	4

6.1.1 Tier 3 (Experimental) Activities

Experimental activities are activities that had low deployment rates, mixed comfort levels during the workshop and deployments, and mixed understanding levels during deployments. The activities categorized in Tier 3, and listed in Table 6.3, had lower rates of deployment than the rest of the Unplugged curriculum, which indicates that the teachers shied away from using these activities for some reason. Despite the issues that exist with these activities, most of the teachers who used these activities plan to use them again, which indicates it might be worth taking time to improve these activities.

Table 6.3: List of Tier 3 Activities

Activity	Workshop Comfort	Deployment Comfort	Deployment Understanding	# of Deployments
Parity and Error Detection	Extremely High	High	Comfortable	4
Artificial Intelligence	Moderate	Moderate	Moderate	4
Deadlock and Routing	High	Comfortable	Comfortable	2
Sorting	N/A	High	Moderate	2
Finite State Automata (FSA)	Moderate	Comfortable	Comfortable	1

6.2 Binary Numbers

The Binary Numbers activity had the highest level of both comfort and understanding among the activities. During the workshop, teachers expressed high levels of comfort and were able to complete the assessments with only minor and sporadic errors. This level of understanding and comfort translated well to deployment results, as 13 of the 14 teachers who deployed at least one activity included Binary Numbers. Furthermore, all teachers who deployed this lesson plan to use it again.

The Binary Numbers lesson is easy to deploy and makes a tangible connection to real CS concepts. This lesson plan could serve as a template for other CS Unplugged activities.

6.3 Image Representation

During the workshop, teachers reported only moderate levels of comfort towards the Image Representation activity. This level of comfort may not be accurate, however, as the introduction to this activity was abbreviated and therefore did not include adequate time for teachers to understand the image encoding scheme. Another issue during the workshop was that the Image Representation activity immediately followed Binary Numbers. This sequence led to some confusion, as teachers immediately tried to apply what they had just learned to Image Representation. Though the Image Representation lesson does use 1's (white) and 0's (black) as the building blocks for the encoding scheme, this activity does not make use of binary numbers per se.

Despite the aforementioned issues, the deployment rate of the Image Representation activity was high, with 10 teachers deciding to use this activity in their class. After teachers deployed the activity in their classrooms they reported a much higher level of comfort. Eight of the teachers stated that they were definitely planning to use the activity again. One teacher indicated that reusing the activity was possible, but that the concept was hard for some of the students. The final teacher stated that the lesson didn't fit as the teachers had hoped.

The Image Representation lesson is representative of an Unplugged lesson that maintains a good balance between simplicity and connections to real-world applications. Several teachers indicated that students really enjoyed this activity, and that they would like to expand upon the material (e.g., exploring color images rather than just black and white).

6.4 MST

During the workshop, teachers reported high levels of comfort towards the MST activity and completed the worksheet with minimal error. The rate of deployment was high, with eight teachers deploying this activity in their classroom. All of the teachers who deployed the activity in their classrooms reported that they would use the activity again.

The MST lesson is easy to deploy and engages the students well. This activity is not without issue, however, as many of the teachers who deployed this lesson in their classroom stated that they felt as if they needed more background on the material and that they did not quite understand the connections to real world applications.

6.5 Cryptography

During the workshop, the teachers reported extremely high levels of comfort towards all facets of the lesson and were able to successfully complete the activities with no errors. However, the teachers indicated that in spite of the understanding the mechanics and content of the lesson, they didn't think they completely understood the activity because they couldn't connect the material in the lesson to real world activities. Despite this deficiency, all seven teachers who deployed this activity are planning to use this lesson again.

The Cryptography lesson is easy to deploy and students have generally found it engaging. Additional connections should be made to real world uses of cryptography to address the concerns expressed by the teachers.

6.6 Computer Vision (CV)

During the workshop, the teachers reported only moderate levels of comfort towards the CV activity. Some of the teachers reported that they were not sure why the students needed to know the subject being presented while others thought the activity wasn't very engaging. These concerns led to a moderate rate of deployment, i.e., the CV lesson was deployed by six teachers. Following the deployments, all teachers who used this activity reported high levels of comfort, and five indicated they will definitely use the activity again. We note, however, that the one teacher who was not sure whether to deploy again stated that students who have not had any computer experience found it interesting.

Overall, the CV lesson makes good connections to real-world applications, but may not be as engaging as the other Unplugged lesson plans. While the worksheets are representative of how CV works, they can be tedious and time-consuming and should be replaced with more engaging worksheets.

6.7 Artificial Intelligence (AI)

The results for this activity during the workshop were mixed, with several teachers rating the logistics, usage, and material as uncomfortable. Many of the teachers were confused by the Turing Test activity and did not understand why the Turing Test was important. In addition, some of the teachers felt that the lesson plan contained too much down time and would not be engaging. The lower levels of comfort and understanding translated into lower deployment rates, as only four teachers used this lesson plan in their classrooms. Concerns with the Turing Test activity were also reported after the deployments, so only two of the four teachers indicated they would use the activity again. One teacher mentioned that the AI discussion really engaged the students.

Despite mixed results, AI, if improved, has a future as an Unplugged lesson plan due to its connection to cutting-edge technology and popular mention in society. More background on the Turing Test activity needs to be given to the teachers and another activity or worksheet needs to be added to the lesson in order to increase student engagement.

6.8 Parity and Error Detection

Teachers attending the workshop reported high levels of comfort towards the Parity and Error Detection activity and were able to successfully complete the activities with minimal error. These high levels of comfort did not translate to a high rate of deployment, however, as only four teachers deployed the lesson in their classroom. The teachers who deployed the activity reported high levels of comfort with the activity and moderate levels of understanding with the material. All of the teachers who deployed the activity stated that they would use the activity again. The teachers mentioned that the students were highly engaged by the magic trick demonstration but that they felt like their understanding was not as high as they would have liked it to be.

The Parity and Error Detection lesson engages students well, but additional refinements are needed to help teachers understand the core concept and connections to real-world usage. In addition, the worksheet needs to be reformatted in order to present clearer instructions to the teachers.

6.9 Searching

The Searching activity was well received during the workshop, with teachers reporting extremely high levels of comfort. The teachers were also able to proficiently complete the activity's worksheets with minimal error, but the final project results were fairly low, which demonstrated that they may have had some difficulty understanding the material. Despite positive workshop results, the Searching activity had a low rate of deployment, with only five teachers using this activity in their classrooms. All of the teachers that deployed this activity mentioned that the format of the worksheets was confusing for the students. Four teachers indicated they would use this activity again, as the teachers recognized that binary search is an important concept. The one teacher who stated that they would not deploy this activity again mentioned that they were unable to see the real-world connections from the activity ("I did not think this lesson did a very good job connecting how computers search for items”). Most likely this teacher wanted to be able to link the activity to Google search, rather than a low-level algorithm.

The Searching activity is an example of an Unplugged lesson that connects well to real-world usages, but not to examples that would be familiar to most non-technical people. In addition, while the concept that a computer can only look at two items at a time is easy to demonstrate in large group activities and lecture times, it is much harder to do on a smaller scale, as evidenced by the questions raised about the worksheets. Binary search is most beneficial when searching large volumes of data and more difficult to appreciate when there are only 13 items (as in the worksheet).

6.10 Deadlock and Routing

During the workshop, the teachers reported high levels of comfort towards the Deadlock and Routing activity. A few of the teachers expressed some concerns about the amount of preparation time and setup needed for the initial kinesthetic activity. Therefore, it is not surprising that only two teachers deployed the Deadlock and Routing activity. After deployment, both teachers reported only moderate levels of comfort and low levels of understanding. The teachers who deployed the activity mentioned that they did not feel like they understood how the concept worked in real life situations. Despite these issues, both teachers indicated they might use the activity again, with one teacher indicating they liked the client/server aspect and the other teacher stating that the activity would get better with more practice.

It is important to note that Deadlock and Routing did not undergo the same revision process that the other Unplugged lesson plans went through in the early stages of this research. While the concept and engagement is promising, this lesson needs to be iterated upon more before it should be used by additional teachers. Specifically, more background information on the topic needs to be included in the lesson plan and the activities themselves need to be reviewed and tweaked as needed.

6.11 Sorting

The Sorting activity was not included in the workshop as a result of the research team deciding that there were too many issues with the material to deploy it in the classroom. However, the material was posted on the Unplugged website, and two teachers who did not attend the workshop deployed the Sorting activity. The teachers reported moderate levels of comfort and understanding towards the activity. Both teachers that deployed the Sorting activity stated that they would use the lesson again.

The Sorting activity was not used in the workshop due to issues that are similar to Searching, namely, hidden data is hard to represent through individual exercises. Unlike Searching, Sorting does not have an engaging large group kinesthetic demonstration. In order for Sorting to become a solid Unplugged lesson, these two issues must be fixed.

6.12 Finite State Automata (FSA)

The FSA activity was not as well received during the workshop; teachers expressed only moderate comfort with the activity, and several teachers had difficulty completing the assessments. It is, therefore, not surprising that only one teacher deployed the FSA activity. The teacher who deployed the activity stated that they intend to use it again. During the semi-structured interviews, many teachers stated that they refrained from using the lesson because it was too complicated. Some teachers mentioned that the lesson plan didn’t fit with their curriculum during the deployment window and that they may still deploy the FSA activity later in the school year.

The FSA activity has a few flaws that prevent it from being used in the classroom. While the actual material was reported to be straightforward to understand, the complexity of the kinesthetic activity, along with incomplete connections to real world uses of FSA, prevented teachers from using the activity. If FSA is to become suitable for classroom use, the kinesthetic activity needs to be reworked and more concrete real world examples need to be included in the lesson plan.

6.13 Curriculum

While looking at the results on a per-activity basis helps determine which activities the teachers used and why they were selected, it is important to highlight some overarching threads between the activities themselves and the teachers that deployed them. Section 6.13.1 considers trends in the deployment rate of the activities.

6.13.1 Assessments vs No Assessments

During the workshop, the teachers rated their comfort levels in activities with assessments (Binary Numbers, Cryptography, Finite State Automata, Minimal Spanning Trees, Searching, and Parity and Error Detection) higher than the lessons without assessments (AI, Image Representation, CV, and Deadlock and Routing), as shown in Figure 6.1. The logistics comfort of activities that do not have assessments (3.92 average) is lower than that of the activities that have assessments (4.55 average). It is recommended that teacher-specific assessments be created to give teachers a way to assess their own understanding of the material.

When we consider the deployment comfort results from the experience reports, the gap between the levels of comfort between activities with and without assessments is minimal, as shown in Figure 6.2. The overall comfort levels regressed to the levels similar to that of abstract lessons surveyed in the workshop. We note that bias may exist in the Grading Comfort results for “No Assessment"; in the “No Assessment” case, perhaps there is nothing to grade (e.g. Artificial Intelligence).

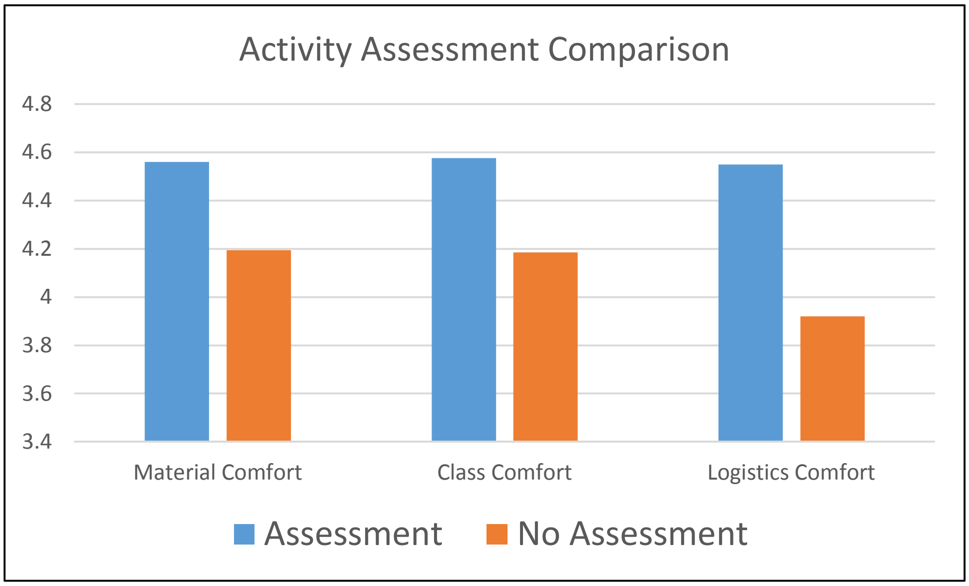


Figure 6.1: Assessment vs No Assessment (Workshop Results)

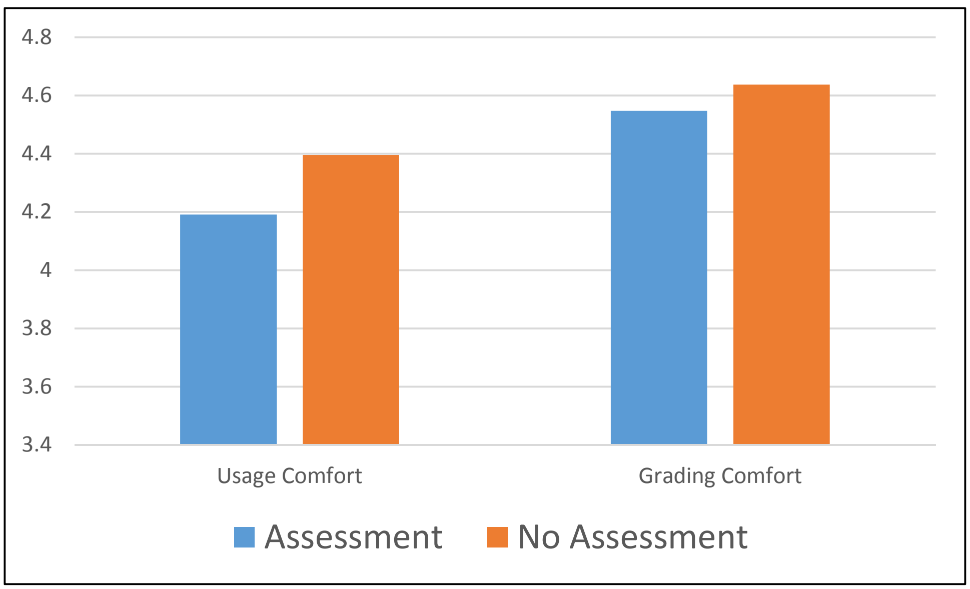


Figure 6.2: Assessment vs No Assessment (Experience Report Results)

When we consider the actual deployment statistics, the activities that the teachers committed to deploying after the workshop correlated to whether or not the activity included an assessment instrument, as shown in Figure 6.3.

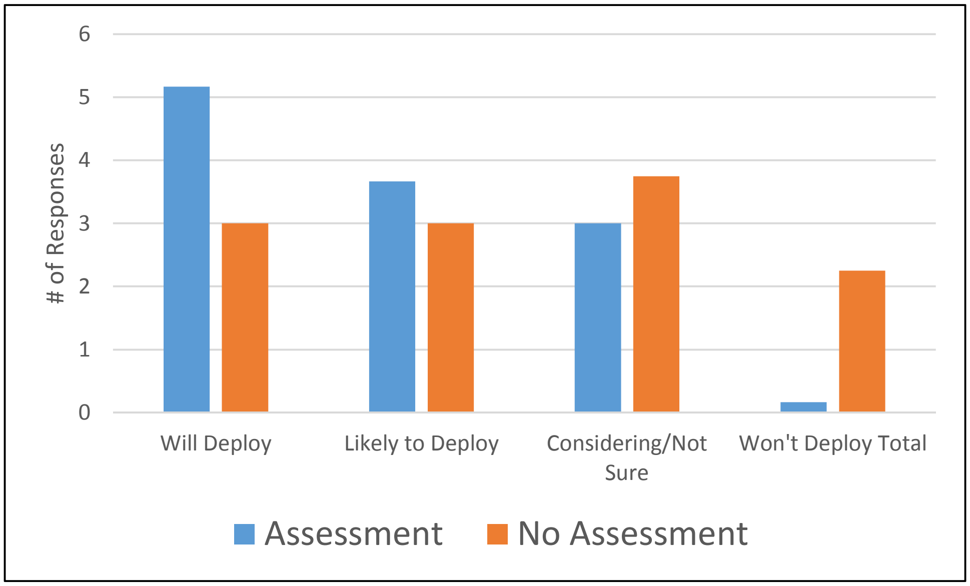


Figure 6.3: Deployment commitment comparison (Assessment vs. No Assessment)

When we consider the individual activities however (as shown in Table 5.7), we see that the deployment rate of an activity did not correlate to whether or not the activity had an assessment. For example, Image Representation was the second most deployed activity and CV was the fifth most deployed activity; neither of these activities have assessments.

As mentioned in the semi-structured interviews, the teachers made their activity selection based on their level of comfort with the lesson, perceived student engagement, and what lessons fit best with their existing curriculum. Thus, while teachers initially selected lessons that are the most comfortable for them, other factors influenced a teacher's usage of a CS Unplugged activity.

6.13.2 Workshop Attendance

Several of the teachers who deployed lessons in the classroom did not attend the workshop. Thus, it is important to compare the levels of comfort between teachers that attended the workshop and teachers that did not attend the workshop (see Figure 6.5). Due to the small sample size, we note these results are not statistically significant; however, we also note that the average usage comfort for those who attended the workshop was approximately 4.4 compared to 4.1 for those who did not attend. Overall, it appears that teachers who attended the workshop were slightly more comfortable in using and grading the activities. For example, teachers who attended the workshop had an average of approximately 4.7 for grading comfort, while those who did not attend had an average of 4.4. It is possible that attending the workshop yields greater depth of understanding; we cannot, however, draw any strong conclusions from these results. We are glad that teachers who did not attend the workshop still had relatively high (>4) ratings for both usage and grading comfort.

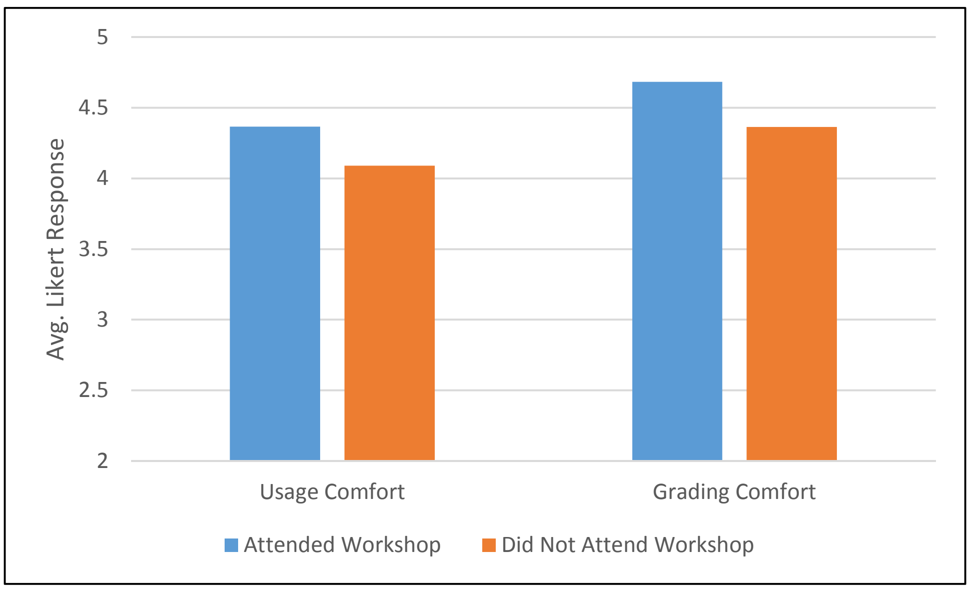


Figure 6.4: Workshop attendance and deployment comfort

CHAPTER 7: CONCLUSIONS AND FUTURE WORK

The goal of this research project was to answer three questions. The following three sections discuss the conclusions that can be drawn from the methodology, results, and analysis of the work presented as part of this thesis.

7.1 Do teachers feel confident teaching CS Unplugged activities?

Through the results of the Likert-scale questions assessing comfort, we conclude overall that teachers feel comfortable with the logistics, the material, and the use of the Unplugged lessons. There are, however, noticeable differences in the teachers' comfort level between some of the activities. In general, teachers are comfortable with all of the activities except AI, Deadlock and Routing, and FSA.

One unique aspect of CS Unplugged is the kinesthetic nature of the activities. While potentially engaging, this is an aspect that may be foreign to teachers. Based on both Likert-scale questions and open responses, teachers have indicated there were some challenges with the kinesthetic nature of the activities. In some cases teachers have stated they need more practice to feel comfortable. In other cases (e.g., FSA), the teachers simply chose not to deploy the activity.

Lessons that incorporate a measurable assessment in the plan were initially viewed more favorably and resulted in higher comfort and confidence levels than the activities that contained no such assessment. While the main focus for CS Unplugged activities should not be worksheets, having assessments in the curriculum allows for teachers to check their understanding of the material and provides some comfort in an assessment-driven environment.

For this study there were only 4 teachers who deployed activities but did not attend the workshop. Thus, no strong conclusions the value of attending a CS Unplugged workshop can be made. Based on the experience reports, we can say that teachers who did not attend the workshop were able to successfully deploy the activities and felt reasonably comfortable. We hypothesize, however, that attending a workshop might increase the level of comfort and encourage teachers to deploy a broader range of activities.

7.2 Do teachers understand the concepts being taught?

Teachers' understanding was assessed through both direct and indirect measures. The workshop assessments provide the only direct measure. Overall, the teachers were able to complete the worksheets and assessments presented in the workshop with a high level of proficiency. These results are not comprehensive though, as not all activities have content assessments. As with the level of comfort, however, there are some notable differences between activities. Teachers were generally proficient with Binary Numbers, Cryptography, Parity and Error Detection, MST, and Searching. Teachers did not perform as well on the FSA assessments. These results indicate that teachers do understand most of the CS Unplugged activities well enough to teach them.

The indirect measures for this question (i.e., self-reports) include Likert-scale questions from the workshop and experience reports as well as open-response questions and semi-structured interviews. Results on the Likert-scale questions demonstrated that teachers believed that they understood the material. Through the semi-structured interviews, it was revealed that some of the teachers tied their level of understanding to their understanding of the subject as a whole, rather than the subject presented in the lesson plan. Thus, adding more background supporting materials would increase teachers' level of understanding.

7.3 Will teachers use CS Unplugged in their classrooms?

Based on the number of Unplugged activities deployed by the participating teachers (61 during our collection period), we conclude that teachers are able to use lessons from the CS Unplugged curriculum in their classrooms. Even more important, all of the teachers stated that they would use some of the activities again in future lessons, with 88% of the experience reports submitted explicitly stating that they would use that specific activity again. Based on the results from the experience reports plus the semi-structured interviews, we conclude that the lesson plans are generally in a format that teachers are able to use, the material is at a level that is appropriate for middle school students, and teachers believe that their students find the activities engaging and are learning important concepts.

Despite this success, a few of the lessons may not be well suited for a traditional middle-school classroom environment. For example, the FSA lesson plan contains material that is very abstract, and the AI lesson does not have sufficient engagement or rigor.

7.4 Future Work

Through this research, we have shown via quantitative and qualitative data that there is indeed a place for CS Unplugged activities in a traditional classroom setting. We have shown that teachers are comfortable and confident with the lesson plans, both in theory and in practice. The workshop surveys, assessment scores, and experience report questions formatively demonstrate that the teachers do indeed understand the material. There is, however, still work to be done on the activities themselves. It is recommended that the activities be publicly categorized according to the tiers defined in our Analysis (Section 6.1). For the Tier 1 activities, we also suggest:

- Review all of the lesson plans to ensure correct spelling and grammar.
- Add additional links to background information and resources to strengthen teacher understanding.

For the Tier 2 activities, we suggest:

- Review all of the lesson plans to ensure that the content is communicated clearly.
- Review the activity instructions to minimize confusion.
- Ensure that the lessons' activities are engaging and not tedious.
- Ensure that the lessons' real-world connections are extremely clear.

Lastly, for the Tier 3 activities, we suggest:

- Re-evaluate the entire lesson plan structure and topic.
- Review the explanation of the topics' core concepts and, perhaps, narrow the focus.
- Revise the complex activities to strengthen teachers' comfort levels with using these activities in the classroom.

The grant website should be updated so that teachers are aware of these tiers.

Finally, teachers will not deploy these activities if they are not aware that they exist. We are currently working with the National Center for Women & Information Technology (NCWIT) to include these activities within their "CS Unplugged in a Box." Additional venues should be explored for promoting the activities to interested teachers.

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APPENDIX A: LESSON PLAN SURVEYS

Binary Numbers

Question	Teacher Response(s)
Did you watch the “Unplugged: Binary Part 1” video that was provided in the lesson plan?	No (2)
How much did the video increase your understanding of binary numbers?	DID NOT ANSWER
How engaging was the video?	DID NOT ANSWER
Was anything in the video confusing?	DID NOT ANSWER
The lesson plan explains how to deploy the counting group activity. Based on this description, how comfortable would you be doing the whole class demonstration?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding Worksheet 1?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding the “What’s the Number” (minimum bits) worksheet?	Very Comfortable (2)
The lesson plan includes a “what’s it all about” section to relate this activity to computer science. How comfortable would you be leading that whole class discussion?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding the “Check Your Understanding” worksheet?	Very Comfortable (2)
The lesson plan explains how to deploy the “Binary Go Fish” activity. Based on this description, how comfortable would you be doing the whole class demonstration?	Very Comfortable (1), Somewhat Comfortable (1)

Binary Numbers cont.

What activity do you feel needs additional explanation through a video demonstration?	None (1), Other (1) ["A general idea of what you want to be learned would be valuable for me"]
How strong are the lesson plan's connections to real world concepts?	Strong (1), Somewhat Strong (1)
Do you have additional comments regarding the lesson plan for binary numbers?	"The students finished the assignment early and there was a little bit of downtime, but that could easily be corrected for a normal school day. " "I think tying the binary number system into something like hex would be good for students to see. They are more apt to see hex numbers than binary and the relationship between the two would be helpful."

Cryptography

Question	**Teacher Response(s)**
The lesson plan explains how to deploy the Caesar cipher activity. Based on this description, how comfortable would you be doing the whole class discussion?	Very Comfortable (1), Somewhat Comfortable (1)
How comfortable would you feel about answering questions regarding Worksheet 1: The Caesar Cipher?	Very Comfortable (1), Somewhat Comfortable (1)
How comfortable would you feel deploying the Packet Villain and Surprise Party worksheet?	Very Comfortable (2)

Cryptography cont.

The lesson plan includes a "what's it all about" section to relate this activity to computer science. How comfortable would you be leading that whole class discussion?	Very Comfortable (2)
How strong are the lesson plan's connections to real world concepts?	Strong (2)
Do you have any additional comments regarding the lesson plan for cryptography?	"I really enjoy this topic. However, it is difficult to convey how many permutations are possible for the cipher. I think some of the students understood it, but not everyone. " "The students loved trying to figure out the messages and encrypt their own message. I think they enjoyed the activities and have a basic understanding of cryptography. Cryptography and its relation to encryption and computer security is a hot topic today. If there's a way to add a short example of how complex real-world cryptography is, that'd be great. Maybe a poster of some sort."

Finite State Automata

Question	**Teacher Response(s)**
Did you watch the "Treasure Hunt" video that was provided in the lesson plan?	No (2)
How much did the video increase your understanding of FSA?	DID NOT ANSWER
How engaging was the video?	DID NOT ANSWER

Finite State Automata cont.

Was anything in the video confusing?	DID NOT ANSWER
The lesson plan explains how to deploy the fruit vendor group activity. Based on this description, how comfortable would you be having the students do the activity and explaining the basics of finite state automata?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding the Robot Dog Worksheet?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding the Chores Robot Worksheet?	Very Comfortable (2)
The lesson plan includes a “what’s it all about” section to relate this activity to computer science. How comfortable would you be leading that whole class discussion?	Very Comfortable (2)
What activity do you feel needs additional explanation through a video demonstration?	Overall Lesson Plan (1), Other (1)
How strong are the lesson plan’s connections to real world concepts?	Strong (1), Somewhat Strong (1)
Do you have any additional comments regarding the lesson plan for FSA?	“This is a difficult concept for students. The fruit vendor activity was confusing for students, at first. Our instructors even struggled a bit with the explanations. One of our instructors tied in some real-life FSA examples during class, which helped. Because of the extra clarification needed, we ran out of time for the last activities – so things seemed rush. A video might help explain the concepts ahead of time so there is less confusion. Maybe take out one activity if this is supposed to fit into a one hour lesson.” “Nothing negative, I enjoy these activities. I think they detail the concept of FSA quite nicely.”

Searching

Question	Teacher Response(s)
Did you watch the “Unplugged: Binary Search” video that was provided in the lesson plan?	Yes (2)
How much did the video increase your understanding of searching algorithms?	Somewhat (2)
How engaging was the video?	Moderately Engaging (2)
Was anything in the video confusing?	“It was very straight forward; however, I had seen this demonstrated before so my answer may be off.“, No(1)
How comfortable would you feel about answering questions regarding the “Raffle Ticket” activity?	Very Comfortable (1), Uncomfortable (1) “I’ve not seen this one before, but I think I could figure it out. I’d need to practice this one”
The lesson plan explains how to deploy the “Ping Pong ball demo” activity. Based on this description, how comfortable would you be doing the whole class demonstration?	Very Comfortable (2)
The lesson plan explains how to deploy the “Guess My Number” activity. Based on this description, how comfortable would you be doing the whole class demonstration?	Very Comfortable (2)
The lesson plan explains how to deploy the “Decision Tree” activity. Based on this description, how comfortable would you be doing the whole class demonstration?	Very Comfortable (1), Somewhat Comfortable (1)
The lesson plan explains how to deploy the “Lion Hunting” activity. Based on this description, how comfortable would you be doing the whole class demonstration?	Very Comfortable (1), Uncomfortable(1) “I’m not quite sure of the rules behind this one, but I may be overthinking it.”

Searching cont.

The lesson plan includes a "what's it all about" section to relate this activity to computer science. How comfortable would you be leading that whole class discussion?	Very Comfortable (1), Somewhat Comfortable (1) "Personally, I'd like to familiarize myself with the contrasting styles of searching before answer questions about this style."
How strong are the lesson plan's connections to real world concepts?	Strong (2)
Do you have addition comments regarding the lesson plan for searching?	"This was a good lesson plan with activities that helped students understand the concept."

Minimum Spanning Trees

Question	**Teacher Response(s)**
How comfortable would you feel about answering questions regarding the "Muddy City" activity?	Very Comfortable (2)
How comfortable would you be doing a whole class discussion on the results of the "Muddy City" activity?	Very Comfortable (1), Somewhat Comfortable (1) – ["A cheat sheet on key points to cover would be helpful"]
How comfortable would you feel deploying the "Halloween Candy" worksheet?	Very Comfortable (1), Somewhat Comfortable (1) – ["Having tricks to solve it efficiently would be helpful"]
The lesson plan includes a "what's it all about" section to relate this activity to computer science. How comfortable would you be leading that whole class discussion?	Very Comfortable (1), Somewhat Comfortable (1)

Minimum Spanning Trees cont.

How strong are the lesson plan's connections to real world concepts?	Strong (2)
How comfortable would you feel deploying the "DIY MST" group activity?	Very Comfortable (2)
Do you have additional comments regarding the lesson plan for Minimum Spanning Trees?	"Students had seen this type of concept before using Khan Academy and by doing the international Bebras challenge. I think the activities were fun and engaging and really helped reinforce these concepts." "Knowing how it relates to CS or IT would be very helpful for me. For instance, relating it to networking would be very helpful for my own understanding."

Parity and Error Detection

Question	Teacher Response(s)
Did you watch the "Magic Trick" video that was provided in the lesson plan?	No (1), No (1) "I've already seen it in person and understand it"
How much did the video increase your understanding of binary numbers?	N/A (2)
How engaging was the video?	N/A (2)
Was anything in the video confusing?	N/A (2)
The lesson plan explains how to deploy the "Magic Trick" activity. Based on this description, how comfortable would you be doing the whole class demonstration?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding the "Magic Trick" activity?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding the ASCII and Parity worksheet?	Very Comfortable (1), Somewhat Comfortable (1) "I would like to know more about other topics such as Unicode and how it is different; however, I am very comfortable talking about these topics"

Parity and Error Detection cont.

The lesson plan explains how to explain the "Magic Trick" activity. Based on this description, how comfortable would you be doing the whole class explanation?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding the "Check Your Understanding" worksheet?	Very Comfortable (2)
The lesson plan includes a "what's it all about" section to relate this activity to computer science. How comfortable would you be leading that whole class discussion?	Very Comfortable (2)
How strong are the lesson plan's connections to real world concepts?	Strong (1)
Do you have additional comments regarding the lesson plan for searching?	"For parity and error checking, the activities were okay. Students didn't seem to quite get the worksheet activity. The magic trick helped students understand the concept of parity." "This is one of my favorites and students frequently get excited about this activity. It is very well designed in my opinion."

Artificial Intelligence

Question	Teacher Response(s)
The lesson plan explains how to deploy the "Intelligence Discussion". Based on this description, how comfortable would you be doing the whole class discussion?	Very Comfortable (1)
How comfortable would you feel about answering questions regarding Artificial Intelligence?	Very Comfortable (1)
How comfortable would you feel deploying the Turing Test activity?	Very Comfortable (1)
The lesson plan includes a "what's it all about" section to relate this activity to computer science. How comfortable would you be leading that whole class discussion?	Very Comfortable (1)
How comfortable would you feel deploying the "Intelligent Piece of Paper" activity?	Somewhat Comfortable (1)
How strong are the lesson plan's connections to real world concepts?	Strong (1)
Do you have additional comments regarding the lesson plan for artificial intelligence?	DID NOT ANSWER (1)

Image Representation

Question	Teacher Response(s)
The lesson plan explains how to deploy an introduction to image representation. Based on this description, how comfortable would you be doing the whole class discussion?	Somewhat Comfortable (1)
How much did the video increase your understanding of binary numbers?	Somewhat Comfortable (1)
How engaging was the video?	Somewhat Comfortable (1)
Was anything in the video confusing?	Somewhat Comfortable (1)
The lesson plan explains how to deploy the counting group activity. Based on this description, how comfortable would you be doing the whole class demonstration?	Somewhat Comfortable (1)
How comfortable would you feel about answering questions regarding Worksheet 1?	Somewhat Strong (1)
Do you have additional comments regarding the lesson plan for image representation?	"Most 6th graders know that binary numbers exist but do not understand how they are used or what they mean. We may need to give more background information so they understand why compression is necessary."

Computer Vision

Question	Teacher Response(s)
The lesson plan explains how to deploy an introduction to computer vision. Based on this description, how comfortable would you be doing the whole class discussion?	Somewhat Comfortable (1)
How comfortable would you feel about answering questions regarding the “Edge Detection” worksheets?	Very Comfortable (1)
How comfortable would you feel deploying the “Image Recognition” worksheet?	Somewhat Comfortable (1)
How comfortable would you feel about answering questions regarding Worksheet 1?	Somewhat Strong (1)
Do you have additional comments regarding the lesson plan for computer vision?	DID NOT ANSWER (1)

Sorting

Question	Teacher Response(s)
Did you watch the “Selection Sort” video that was provided in the lesson plan?	Yes (1)
How much did the video increase your understanding of selection sort algorithms?	Not at all (1)
How engaging was the video?	Moderately Engaging (1)
Was anything in the video confusing?	Yes (1)
Did you watch the “Insertion Sort” video that was provided in the lesson plan?	Yes (1)
How much did the video increase your understanding of selection sort algorithms?	Not at all (1)
How engaging was the video?	Barely Engaging (1)
Was anything in the video confusing?	Yes (1)
The lesson plan explains how to deploy the sorting weights group activity. Based on this description, how comfortable would you be doing the whole class demonstration?	Somewhat Comfortable (1)
The lesson plan explains how to deploy the sorting cards group activity. Based on this description, how comfortable would you be doing the whole class demonstration?	Uncomfortable (1)
How comfortable would you feel about answering questions regarding the Colors Worksheet?	Somewhat Comfortable (1)

Sorting cont.

The lesson plan includes a "what's it all about" section to relate this activity to computer science. How comfortable would you be leading that whole class discussion?	Uncomfortable (1)
How comfortable would you feel about answering questions regarding the "Check Your Understanding" worksheet?	Uncomfortable (1)
How strong are the lesson plan's connections to real world concepts?	Weak (1)
Do you have additional comments regarding the lesson plan for sorting?	"To be successful, students need to clearly understand how this concept applies to computer science through a real-world example. I am not seeing a strong example that students could relate to. They may leave the lesson understanding that there are two ways that data is sorted, but I don't know that they will understand how they are actually used by a computer or why one sorting activity is more advantageous than the other. Students might wonder……. Are there other sorting methodologies? How does the computer know which sorting method to use? How does this impact my use of a computer?"

APPENDIX B: OBSERVATION SURVEYS

Binary Numbers

Question	**Teacher Response(s)**
How comfortable would you be doing the whole class demonstration?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding Worksheet 1?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding the "What's the Number" (minimum bits) worksheet?	Very Comfortable (2)
How comfortable would you be leading the "What's it all about" discussion?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding the "Check Your Understanding" worksheet?	Very Comfortable (2)
How comfortable would you be leading the "Binary Go Fish" activity?	Very Comfortable (1), Somewhat Comfortable (1)
Would you modify the activity in any way?	"I would start out with a very simple example of the students standing in the row at the front of the class. The first example given was okay, but confusing for some students." "I really like adding an element of having the students figure out the pattern without help initially as a lead in. In other words, I give them a riddle and see if they can solve it to gain their interest. "

Binary Numbers cont.

How would you describe the level of student engagement?	"The student engagement was high until they finished the assignment then they quickly became off task. " "Students really loved the go fish game – the other activities interested most students."
In your opinion, does this activity make real-world connections for students?	"I asked the class if they thought Binary code was still used today and several did not know. Some made the connection, but I don't think they realized how it is used in a computer. " "The connection to color representation made a connection with them because we've done a unit on graphic arts using Photoshop. Another connection between hexadecimal and binary might be useful."

Cryptography

Question	**Teacher Response(s)**
How comfortable would you be doing the discussion on Caesar ciphers?	Very Comfortable (1), Somewhat Comfortable (1)
How comfortable would you feel about answering questions regarding Worksheet 1: The Caesar cipher?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding the "Surprise Party" worksheet?	Very Comfortable (2)
How comfortable would you be leading the "What's it all about" discussion?	Very Comfortable (2)
Would you modify the activity in any way?	I really enjoyed the more difficult portions, but it may not be a good fit for 7th grade. Perhaps, 8th grade may be a better place for the letter frequency activities" "I think the activities were right on target. The students were having fun and learning at the same time."

Cryptography cont.

How would you describe the level of student engagement?	"1st class – there was a fair amount of down time, but before they finished they were engaged. 2nd class – they were engaged most of the class and down time was kept to a minimum. " "Students loved these activities and were very engaged."
In your opinion, does this activity make real-world connections for students?	"I think it is starting the conversation, but it would helpful to follow up the next class with a discussion on security and encryption." "This lesson and the activities really connected to our modern day issues with computer and network security. Students are really aware of hackers and mal-ware and the need for encryption. Our speakers also added comments about computer security to enhance these connections."

Finite State Automata

Question	Teacher Response(s)
How comfortable would you be having the students do the "Fruit Vendor" activity and explaining the basics of finite state automata?	Very Comfortable (1), Somewhat Comfortable (1)
How comfortable would you feel about answering questions regarding Worksheet 1?	Somewhat Comfortable (2)
How comfortable would you feel about answering questions regarding the "What's the Number" (minimum bits) worksheet?	Very Comfortable (1), Somewhat Comfortable (1)
How comfortable would you be leading the "What's it all about" discussion?	Somewhat Comfortable (1), Very Uncomfortable (1)
How comfortable would you feel about answering questions regarding the "Check Your Understanding" worksheet?	Very Comfortable (2)

Finite State Automata cont.

Would you modify the activity in any way?	"The first Fruit Stand activity was confusing. I would preface it with a video to get the general idea into their heads. Things were rushed a bit, so maybe take out one activity." "Maybe having mini-erasable white board were the students can create the FSA's as a group."
How would you describe the level of student engagement?	"Students really liked the activities. A good thing about the activities being a little confusing is that students were talking and trouble-shooting their FSA reasoning. That was nice to see." "The Frustrating Fruit vendor is surprisingly effective and students were saying "that's fun." I do believe they are beginning to link FSA concept to that of computers. Students who weren't engaged previously were engaged in this activity. I even saw a few smiles. Linking the FSA concept to a familiar game got most of the boys' attentions and some of the girls. "
In your opinion, does this activity make real-world connections for students?	"I do think the students are grasping that this activity has real world connections. I asked a few students if they thought it was applicable to real life: 'It's just like scratch' 'If you were making a robot, it would be useful' 'I don't how it would be used, but I think it would be useful.'" "Again, I think a video showing how FSAs are used in a real profession would be helpful."

Searching

Question	**Teacher Response(s)**
How comfortable would you be leading the discussion on Binary Search?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding “Raffle Tickets”?	Very Comfortable (1), Somewhat Comfortable (1)
How comfortable would you feel about answering questions regarding the “Dragons and Cows” worksheet?	Very Comfortable (2)
How comfortable would you be leading the “What’s it all about” discussion?	Very Comfortable (1), Somewhat Comfortable (1)
Would you modify the activity in any way?	“Try to minimize down time for students who finish early. Perhaps they could put this towards a larger project in the class. “ “Some of the demonstrations were hard for the whole class to see”
How would you describe the level of student engagement?	“The students are engaged until they think they are done with the activity. Whether they are right or wrong, they tended to zone out once the worksheet was done.” “Students seemed to understand the concept pretty easily and liked the activities.”
In your opinion, does this activity make real-world connections for students?	“Yes, I do think this assignment made a real world impression” “Yes – because finding information quickly and effectively is something they do regularly with their use of the internet. Tying this activity into Google searches, etc. was really effective in making a connection.”

Minimum Spanning Trees

Question	Teacher Response(s)
How comfortable would you be doing the whole class demonstration?	Very Comfortable (1), Somewhat Comfortable (1)
How comfortable would you feel about answering questions regarding Worksheet 1?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding the “Halloween Candy” worksheet?	Very Comfortable (2)
How comfortable would you be leading the “What’s it all about” discussion?	Very Comfortable (1), Somewhat Comfortable (1)
Would you modify the activity in any way?	“Nothing is coming to mind. I liked these activities.” “I would leave the activities the way they are. “
How would you describe the level of student engagement?	“It depended on the class, but these activities (relative to the other deployments) had a higher level of engagement.“ “Students loved the activities and were very engaged.”
In your opinion, does this activity make real-world connections for students?	“Yes – if you tie the activities into electrical and water grids, etc.”

Parity and Error Detection

Question	Teacher Response(s)
How comfortable would you be doing the whole class demonstration?	Very Comfortable (2)
How comfortable would you feel about answering questions regarding Worksheet 1?	Very Comfortable (2)
How comfortable would you be leading the “What’s it all about” discussion?	Very Comfortable (1), Somewhat Comfortable (1)
Would you modify the activity in any way?	“The ASCII storing letters as numbers worksheet was difficult for many students. They liked the magic trick and the penny activity.” “Nothing I can think of, I really think the ‘magic trick’ engages students amazingly well.”
How would you describe the level of student engagement?	“The students’ level of engagement was high for these activities. “ “Students liked the magic trick and penny activity. I think some students thought the ASCII storing letters as numbers worksheet was too difficult. But – some students were also gone during the binary lesson because of PARCC testing. They were missing a key piece of knowledge when they tried the ASCII worksheet.”

Parity and Error Detection cont.

In your opinion, does this activity make real-world connections for students?	Anecdotal reflections from students: This relates to real world computing because computers sometimes send messages and they get scrambled during the process. The computer keeps track of that chunk then sends it back to the owner of the coding. Computers will also try to figure out the message but sometimes they can't because there is an even number of 1's and 0's” “This translates to the world of computing because Binary is how computers run. They can send messages in binary which send to other computers and can be read. If there are mistakes made, the computer goes through the same process that we learned today. ” “This relates to the world of computing because it is one of the ways computers can detect errors in messages. When something like a text message is sent from your computer and phone this is a possible way for the computer to detect errors by making parodies for each strand of code. This is also used to detect errors in other things sent from computer to computer like files.”

Artificial Intelligence

Question	**Teacher Response(s)**
How comfortable would you be leading the discussion on Artificial Intelligence?	Very Comfortable (1)
How comfortable would you feel about answering questions regarding The Turing Test Activity?	Very Comfortable (1)
How comfortable would you feel about answering questions regarding the “Intelligent Piece of Paper” activity?	Very Comfortable (1)
How comfortable would you be leading the “What’s it all about” discussion?	Very Comfortable (1)
Would you modify the activity in any way?	“I would spend more time relating this activity to what 6th graders think is actually happening in the world regard to AI. Sixth graders often believe that what they see in Hollywood movies is AI.”
How would you describe the level of student engagement?	“High level of engagement for most students”
In your opinion, does this activity make real-world connections for students?	“See comment above.”

Image Representation

Question	Teacher Response(s)
How comfortable would you be leading the discussion on Image Representation?	Very Comfortable (1)
How comfortable would you feel about answering questions regarding the Hidden Images Worksheet?	Very Comfortable (1)
How comfortable would you feel about answering questions regarding the “Sharing with a Friend” activity?	Very Comfortable (1)
How comfortable would you feel about answering questions regarding the “Compression” activity?	Very Comfortable (1)
How comfortable would you be leading the “What’s it all about” discussion?	Very Comfortable (1)
Would you modify the activity in any way?	“Further discuss the real-world application of these concepts.”
How would you describe the level of student engagement?	“Level of engagement varied dramatically depending on the CSM teacher presenting the material.”
In your opinion, does this activity make real-world connections for students?	“This lesson did a better job than the previous lesson (AI) at connecting to real-world examples, but 6th graders need even more of a deliberate connection.”

Computer Vision

Question	Teacher Response(s)
How comfortable would you be leading the discussion on Computer Vision?	Very Comfortable (1)
How comfortable would you feel about answering questions regarding the Edge Detection worksheets?	Very Comfortable (1)
How comfortable would you feel about answering questions regarding the Image Recognition worksheet?	Somewhat Comfortable (1)
How comfortable would you be leading the “What’s it all about” discussion?	Very Comfortable (1)
Would you modify the activity in any way?	“The more you can connect to real world examples the better. Loved the comparison to self-driving car. Perhaps next time you can find a short youtube video to demonstrate that technology.”
How would you describe the level of student engagement?	“Medium high. Engagement levels definitely changed depending on who was presenting the material.”
In your opinion, does this activity make real-world connections for students?	“Yes. Students related to driverless cars. Like I said earlier, the more connections the better. I am not certain that students understood why breaking animals into shapes related to them or their use of computers.”

APPENDIX C: SAMPLE WORKSHOP AGENDA

Day 1	What
8:30-9:00	Breakfast
9:00-9:15	Introduction to Unplugged
9:15-10:00	Binary Numbers Activity
10:00-10:45	Image Rep
10:45-11:00	Break
11:00-11:45	Artificial Intelligence
11:45-12:00	What is Computational Thinking?
12:00-1:00	Lunch @ Mines Market
1:00-1:45	Computer Vision
1:45:-2:15	CS+X
2:15-3:00	Minimal Spanning Trees
3:00-3:15	Break
3:15-4:00	Binary Search

Day 2	What
8:30-9:00	Breakfast
9:00-9:45	Parity and Error Detection
9:45-10:30	Cryptography Activity
10:30-10:45	Break
10:45-10:55	Field Session Presentation
10:55-11:05	Field Session Presentation
11:05-11:15	Dam Research
11:15-12:00	Deadlock and Routing
12:00-1:00	Lunch in classroom
1:00-1:30	Inclusive Pedagogy
1:30-2:15	Finite State Automata Activity
2:15-2:30	Break
2:30-3:00	Teacher Experience with Unplugged
3:00-3:30	Post-Workshop Assessment
3:30-4:00	Workshop survey/follow-up details

APPENDIX D: ACTIVITY SURVEY

CS Unplugged Activity Survey

The purpose of this survey is for you to describe your level of comfort with a CS Unplugged activity. This survey is NOT anonymous, as we hope to work in partnership with you. Please be as honest as possible. If you don't like the activity or aren't comfortable, please feel free to let us know.

* Required

1. **Name** *

2. **Which CS Unplugged lesson are you rating?** *
   Mark only one oval.
   - Binary Numbers
   - Cryptography
   - Finite State Automata
   - Searching
   - Minimum Spanning Trees
   - Error Detection and Parity
   - Artificial Intelligence
   - Image Representation
   - Computer Vision
   - Sorting
   - Routing and Deadlock

3. **How clear are the directions for this activity?** *
   Mark only one oval.

	1	2	3	4	5	
Not at all						Extremely

4. **How engaging do you feel this activity would be with your students?** *
   Mark only one oval.

	1	2	3	4	5	
Not at all						Extremely

5. **Rate your understanding of the material presented for this activity** *
Mark only one oval.

- ( ) I understand this topic well because I had prior knowledge
- ( ) I understand this topic well based on the presentation today
- ( ) I understand this topic fairly well but will need to review before presenting to my class
- ( ) I understand the topic but not well enough to present to my class
- ( ) I feel somewhat confused about this topic

6. **How comfortable would you be using this activity in your classroom?** *
Mark only one oval.

	1	2	3	4	5	
Not at all	( )	( )	( )	( )	( )	Extremely

7. **How comfortable are you with the kinesthetic/group work (e.g., logistics, timing, materials, etc.)** *
Mark only one oval.

	1	2	3	4	5	
Not at all	( )	( )	( )	( )	( )	Extremely

8. **How could we modify this activity to be more engaging, relevant or easy to deploy?**

____

____

____

____

____

Name: ______________________________

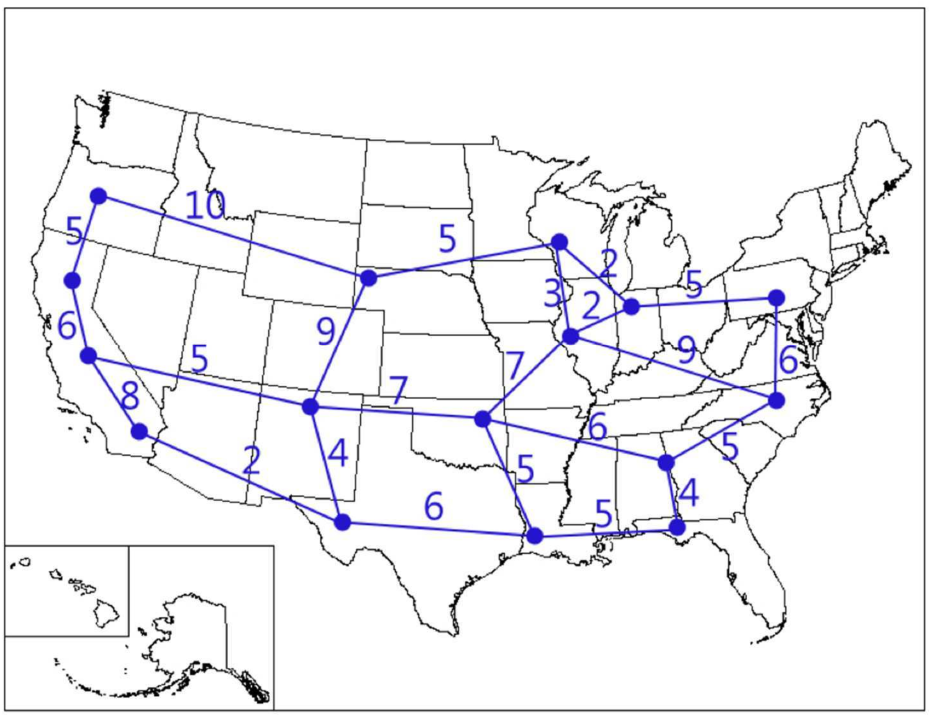
Carnytown Carnival Murder Mystery

While visiting the Carnytown Carnival, you found a dead body! Can you help solve the murder at the carnival before it's too late and the carnival gets shut down forever?

Detective Notes: Tammy

Tammy helps send all the carnival equipment on trains to the next city where the carnival will set up. In the map below, each dot is a city where the carnival will be this year. The numbers next to each line represent the cost (in millions) to build railroad tracks between those two cities. Tammy needs your help in connecting all of the cities using the smallest amount of cash.

Shade the lines where the railroad tracks should be laid so that the railroad company uses the least amount of money to build the tracks.



How many tracks do you need to connect all 16 cities? ______________________________

Name: ______________________________

Detective Notes: Larry

Larry is trying to fix the robotic fortune telling robot that lives in the park. He needs your help to make sure that the robot is working properly. This robot follows the following set of rules:

The Rules (the states are in bold):

1. If the teller is **sleeping**, *insert a coin* and the teller will **talk**
2. If the teller is **sleeping**, *ask a question* and the teller will **tell a joke**
3. If the teller is **telling a joke**, *wait* and the teller will **sleep**
4. If the teller is **talking**, *wait*, and and the teller will **demand a question**
5. If the teller is **demanding a question**, *ask a question* and the teller will **answer**
6. After the teller **answers**, *insert a coin* and the teller will **talk**

Use the blank space below to work on a solution to this problem by organizing the states and transitions.

Circle any of the following schedules if they follow the teller's rules, starting from the sleeping state.

1. Coin	1. Ask	1. Coin
2. Wait	2. Wait	2. Wait
3. Ask	3. Coin	3. Wait
4. Coin	4. Wait	4. Coin

How many schedules did you circle?______________________

Name: ______________________________

Detective Notes: Sammy

Sammy loves writing secret messages!

Sammy wrote messages using numbers. The number system Sammy uses only has 1's and 0's:

Can you decode the following message from Sammy?

0	0	1	0	1	
0	1	0	0	1	
0	0	1	1	1	
0	0	1	0	0	
1	0	1	0	0	

Here are the first few letters from Sammy's system.

A = 0 0 0 0 1
B = 0 0 0 1 0
C = 0 0 0 1 1
D = 0 0 1 0 0

Below, we've listed each letter and its numerical place in the alphabet.

A = 1
B = 2
C = 3
D = 4
E = 5
F = 6
G = 7
H = 8
I = 9
J = 10
K = 11
L = 12
M = 13
N = 14
O = 15
P = 16
Q = 17
R = 18
S = 19
T = 20
U = 21
V = 22
W = 23
X = 24
Y = 25
Z = 26

Name: ______________________________

Detective Notes: Odin

Odin's library had over 16 different antique books. Odin kept everything alphabetized. Unfortunately, the names on the covers have become worn off due to much use, and the books don't have enough differences in shape in order to visually pick out a specific book.

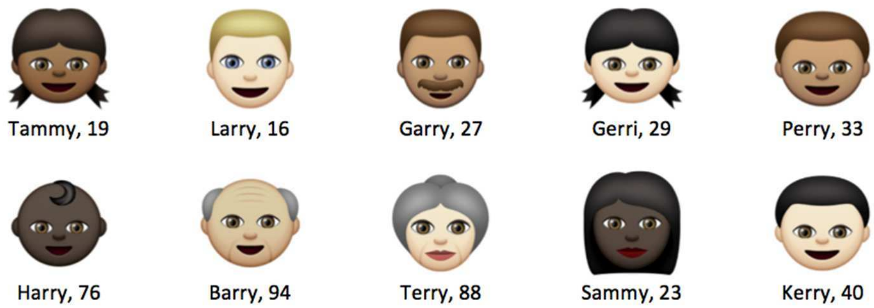
If Odin wanted to read a book, he had to search through his library to find it (he knew the title of the book). **How many items did Odin have to look at in order to find what he was looking for?**

Write your answer here: __________________________

Name: ______________________________

Who Did It?

Collect clues from the activities. Then, add the clues together to determine who the murderer is! Circle the killer! **<u>DON'T TELL ANYONE WHO DID IT!</u>** You don't want to tip the murderer off!



Name: ______________________________

EXTRA: The Guilty in Hiding.

You've cornered the murderer! However, the murderer and a few accomplices ran off and are now in hiding! You know all of the possible hiding places in town. However, you've only just realized that your list of places is actually another puzzle!

Below is a table of the places. You've noticed that the culprits hide in different spots depending on their favorite number, so you've recorded each of their favorite numbers and you are now put in charge of assisting the police in apprehending the suspects.

Larry  10 ________________

Terry  6 ________________

Kerry  31 ________________

Tammy  4 ________________

Gary  21 ________________

Barry  15 ________________

01111	**Diner**
01010	**Motel**
11111	**Gas Station**
10101	**College**
00110	**Ballpark**
00100	**Town Center**

APPENDIX F: WORKSHOP SURVEY

Workshop Survey

* Required

1. **Name**

____

Please rate how likely you would be to deploy the following activities.

2. **Binary Numbers** *

Mark only one oval.

- ◯ Will definitely deploy
- ◯ Likely to deploy
- ◯ Considering/Not sure
- ◯ Will not deploy because activity doesn't relate
- ◯ Will not deploy because activity is not engaging
- ◯ Will not deploy because the material is confusing/unclear
- ◯ Will not deploy due to lack of time in curriculum
- ◯ Will not deploy (other)

3. **Cryptography** *

Mark only one oval.

- ◯ Will definitely deploy
- ◯ Likely to deploy
- ◯ Considering/Not sure
- ◯ Will not deploy because activity doesn't relate
- ◯ Will not deploy because activity is not engaging
- ◯ Will not deploy because the material is confusing/unclear
- ◯ Will not deploy due to lack of time in curriculum
- ◯ Will not deploy (other)

4. **Finite State Automata (FSA)** *
Mark only one oval.

- ◯ Will definitely deploy
- ◯ Likely to deploy
- ◯ Considering/Not sure
- ◯ Will not deploy because activity doesn't relate
- ◯ Will not deploy because activity is not engaging
- ◯ Will not deploy because the material is confusing/unclear
- ◯ Will not deploy due to lack of time in curriculum
- ◯ Will not deploy (other)

5. **Searching** *
Mark only one oval.

- ◯ Will definitely deploy
- ◯ Likely to deploy
- ◯ Considering/Not sure
- ◯ Will not deploy because activity doesn't relate
- ◯ Will not deploy because activity is not engaging
- ◯ Will not deploy because the material is confusing/unclear
- ◯ Will not deploy due to lack of time in curriculum
- ◯ Will not deploy (other)

6. **Minimal Spanning Trees (MST)** *
Mark only one oval.

- ◯ Will definitely deploy
- ◯ Likely to deploy
- ◯ Considering/Not sure
- ◯ Will not deploy because activity doesn't relate
- ◯ Will not deploy because activity is not engaging
- ◯ Will not deploy because the material is confusing/unclear
- ◯ Will not deploy due to lack of time in curriculum
- ◯ Will not deploy (other)

7. **Error Detection and Parity** *

Mark only one oval.

- Will definitely deploy
- Likely to deploy
- Considering/Not sure
- Will not deploy because activity doesn't relate
- Will not deploy because activity is not engaging
- Will not deploy because the material is confusing/unclear
- Will not deploy due to lack of time in curriculum
- Will not deploy (other)

8. **Artificial Intelligence** *

Mark only one oval.

- Will definitely deploy
- Likely to deploy
- Considering/Not sure
- Will not deploy because activity doesn't relate
- Will not deploy because activity is not engaging
- Will not deploy because the material is confusing/unclear
- Will not deploy due to lack of time in curriculum
- Will not deploy (other)

9. **Image Representation** *

Mark only one oval.

- Will definitely deploy
- Likely to deploy
- Considering/Not sure
- Will not deploy because activity doesn't relate
- Will not deploy because activity is not engaging
- Will not deploy because the material is confusing/unclear
- Will not deploy due to lack of time in curriculum
- Will not deploy (other)

10. **Computer Vision** *
Mark only one oval.

- ( ) Will definitely deploy
- ( ) Likely to deploy
- ( ) Considering/Not sure
- ( ) Will not deploy because activity doesn't relate
- ( ) Will not deploy because activity is not engaging
- ( ) Will not deploy because the material is confusing/unclear
- ( ) Will not deploy due to lack of time in curriculum
- ( ) Will not deploy (other)

11. **Deadlock and Routing** *
Mark only one oval.

- ( ) Will definitely deploy
- ( ) Likely to deploy
- ( ) Considering/Not sure
- ( ) Will not deploy because activity doesn't relate
- ( ) Will not deploy because activity is not engaging
- ( ) Will not deploy because the material is confusing/unclear
- ( ) Will not deploy due to lack of time in curriculum
- ( ) Will not deploy (other)

12. **For the activities you marked as "Will not deploy (other)", it would be helpful if you could let us know why.**

13. **Do you have any general concerns with the activities?**

14. **Do you have any comments or concerns regarding the workshop?**

APPENDIX G: EXPERIENCE REPORT

CS Unplugged Experience Report

* Required

1. **Name** *

2. **Activity Deployed** *

   Mark only one oval.

   - Binary Number
   - Cryptography
   - Finite State Automata (FSA)
   - Searching
   - Minimum Spanning Trees (MSA)
   - Error Detection and Parity
   - Artificial Intelligence
   - Image Representation
   - Computer Vision
   - Sorting
   - Deadlock and Routing

3. **Class Type** *

4. **Grade(s)** *

5. **Total # of Students** *

6. **# of Sections** *

7. **How comfortable were you when deploying the activity?** *
Mark only one oval.

	1	2	3	4	5	
Not very	◯	◯	◯	◯	◯	Very

8. **What percentage of the students' questions could you answer confidently?** *

____

9. **How confident are you that you could accurately grade the worksheets (if any)?**
Mark only one oval.

	1	2	3	4	5	
Not very	◯	◯	◯	◯	◯	Very

10. **How would you rate your understanding of the material when presenting it to your class(es)?**
Mark only one oval.

	1	2	3	4	5	
Not very	◯	◯	◯	◯	◯	Very

11. **Do you plan to use this activity again? Why or why not?** *

____
____
____
____
____

12. **Do you think you would benefit from more instruction on the CS concepts this activity covered? Why or why not?** *

____
____
____
____
____

13. **Did you modify the activity in some way to fit your course?** *

14. **Did you encounter any difficulties?** *

15. **What suggestions do you have for us and/or other teachers who might want to use this activity?** *

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APPENDIX H: SEMI-STRUCTURED INTERVIEW QUESTIONS

Semi-Structured Interview Questions for CS Unplugged Follow Up

Assent Script:

I'm going to ask you some questions to help you reflect on your experience teaching the CS Unplugged activities this past year that you were introduced to in our workshop over the summer. We will use your responses, along with those of other teachers, to improve the structure of the activities as well as our support of teachers using them. We would like to record this interview so we can be sure to capture all that you say. No one other than the research and program team will have access to the interview recordings or transcriptions. Is it okay with you to record the audio of this conversation? This will take anywhere from 20 to 30 minutes. Any questions? Great, let's begin.

Questions:

Overall, did you feel that CS Unplugged was a good use of your class time?

Overall, did you feel that your class learned from the activities?

Do you think that the students learned what you intended to teach from these activities?

Did you feel that the current available resources supported your teaching?

Were these activities easy to deploy?

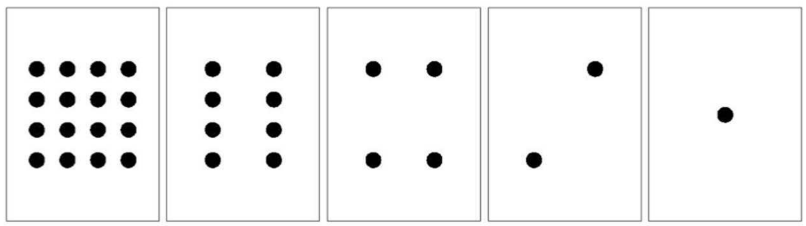
How prepared did you feel to teach these activities?

Did you feel that the kids enjoyed the activities?

What student questions, if any, were hard for you to answer?

APPENDIX I: BINARY NUMBER ASSESSMENTS

Check Your Understanding



1. What is the next number in the sequence?

00001 00010 00011 00100 ______

2. What decimal number is represented by 01011?

3. How would you write the number 20 in binary?

4. What is the largest number you can represent using five cards (i.e., five bits)?

5. What is the largest number you could represent if you had only three cards?

6. How many cards (bits) would you need to represent the number 63?

APPENDIX J: BINARY NUMBERS ASSESSMENT RUBRIC

Binary Numbers: Check Your Understanding

	3 Proficient	2 Partially Proficient	1 Unsatisfactory
What is the next number in the sequence?	Student correctly identifies the pattern and answer 00101 (five).	Student correctly identifies the answer should be in binary, but does not recognize the pattern and gives an incorrect number.	Student didn't attempt the problem or answered in decimal numbers.
What decimal number is represented by 01011?	Student converts from binary to decimal and answers with 11.	Student converts from binary to decimal, but gives an incorrect answer (such as re-converting 11 to decimal number 3)	Student does not convert the number to a decimal representation, or simply adds a decimal point to the binary number.
How would you write the number 20 in binary?	Student correctly answers 10100.	Student answers incorrectly but gives some level of justification explaining their reasoning.	Student does not attempt the problem or gives an answer using decimal numbers.
What is the largest number you can represent using five cards (i.e., five bits)?	Student answers 31.	Student gives an incorrect answer but with justification behind their thought process.	Student does not attempt the problem or gives an answer without justification.
What is the largest number you could represent if you had only three cards?	Student answers 7.	Student answers 28 (the highest of the five bit cards on the worksheet) or another incorrect answer, but gives justification.	Student answers incorrectly and without justification.
How many cards (bits) would you need to represent the number 63?	Student answers 6.	Student answers 7 bits (off by one)	Student answers 5 or fewer bits (this should be obviously wrong with the bit cards printed at the top), or another number without justification.

APPENDIX K: CRYPTOGRAPHY ASSESSMENT

Worksheet 1

The Caesar Cipher

Julius Caesar used a simple substitution cipher to send messages to his troops. He substituted each letter by the letter that was 3 places further along in the alphabet, so that “a” was replaced with “D”, “b” with “E” and so on.

Part I. Complete the table below to show what each letter is enciphered as using this system.

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
D	E	F																							

Part II. Using the Caesar Cipher, encode the name of your school. Did your partner get the same answer?

____

Part III. Computer scientists would call 3 the “key” for this cipher. How many different keys are possible?
____

Part IV. Decode this message, which was encoded using the Caesar cipher from the table above:

Z	K	D	W		G	R		B	R	X		J	H	W		Z	K	H	Q		B	R	X	

F	U	R	V	V		D		V	Q	R	Z	P	D	Q		Z	L	W	K		D	

							?										
Y	D	P	S	L	U	H	?		I	U	R	V	W	E	L	W	H

Material from http://crypto.interactive-maths.com/

APPENDIX L: CRYPTOGRAPHY ASSESSMENT RUBRIC

Cryptology Worksheets

	3 Proficient	2 Partially Proficient	1 Unsatisfactory
Caesar Ciphers: Encryption	Student is able to complete an existing cipher to encode a plaintext value correctly.	Student can complete a partial Caesar cipher, but is unable to encrypt a plaintext message or inconsistently encrypts data (top-to-bottom *and* bottom-to-top encryption)	Student is unable to demonstrate knowledge of a Caesar cipher, and cannot complete a partial cipher nor use a cipher to encrypt a plaintext message.
Caesar Ciphers: Analyzing	Student acknowledges 25 or 26 possible Caesar ciphers based on the in class cipher.	Student recognizes a number of Caesar ciphers that can be justified using the number of letters in the alphabet (aka 26*26, 26*25, and so on).	Student analyzes the number of possible Caesar cipher keys and answers with a number unrelated to the number of letters in the alphabet.
Caesar Ciphers: Decryption	Student is able to take an encrypted message and a known cipher key to produce a plaintext message.	Student takes an encrypted message and a known cipher to produce a doubly encrypted message.	Student is unable to connect an existing cipher with an encrypted message, and does not produce a message.

APPENDIX M: FINITE STATE AUTOMATA ASSESSMENT (CHORES ROBOT)

Name:_____________

Chores Robot

You have a robot with 2 buttons labeled A and B, if you hit these buttons it will do your chores. It can only do certain chores after it has already done other ones. Use the instructions bellow to create a FSA for your robot, remember to label all the *transitions (actions)* and **states**.

1. If your robot is on **Standby**, you can *press A* and it will **Make your bed**
2. If your robot is on **Standby**, you can *press B* and it will **do the dishes**
3. If your robot is **making your bed** you can, *press A* to get it to **do the laundry** or *press B* to make it return to **standby**
4. If your robot is **doing the dishes** you can *press A* to have it **take out the trash** or *press B* to make it **do the laundry.**
5. If your robot is **doing the laundry** *pressing A* will make it return to **standby**, and *pressing B* will have it **take out the trash**
6. If your robot is **taking out the trash**, *pressing A* will have it **make your bed**, *pressing B* will have it **do the laundry**

What sequence of button pushes will get your robot to do all of your chores, try to list 2 options.

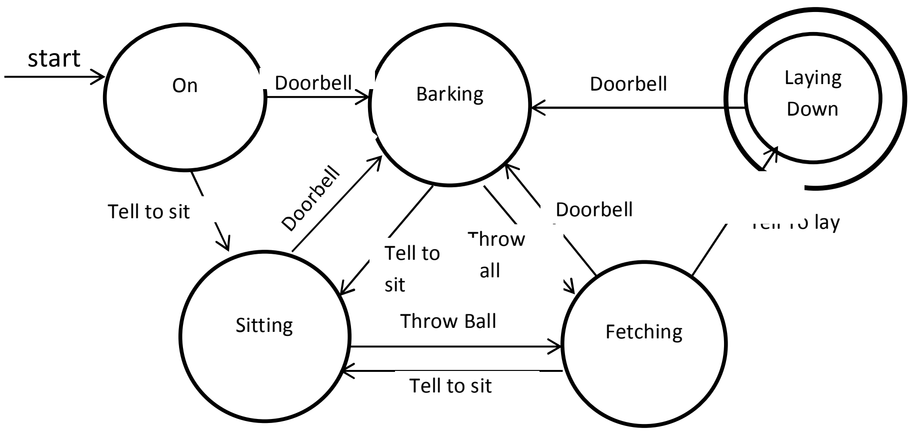
1.

2.

APPENDIX N: FINITE STATE AUTOMATA ASSESSMENT (ROBOT DOG)

Name:___________

Worksheet: Robot Dog



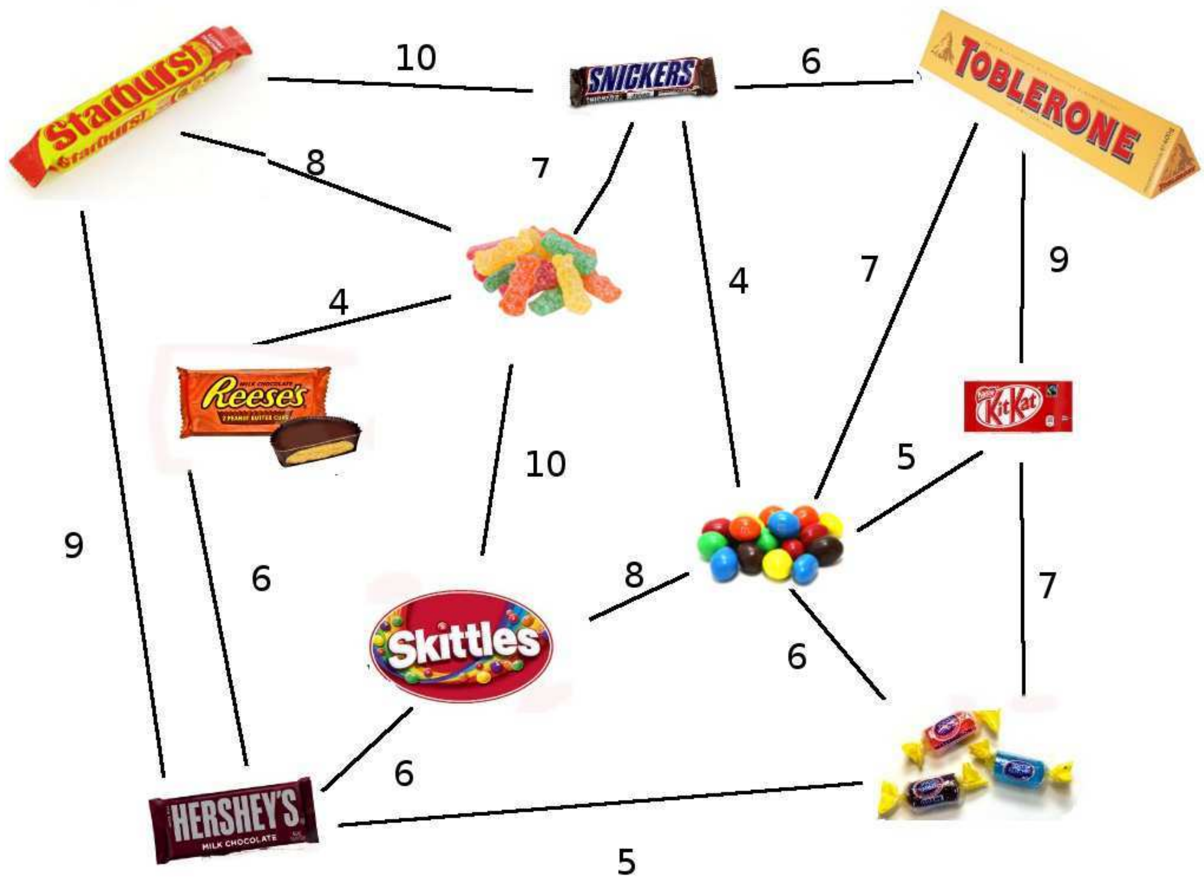
1. Identify the following states
    a. Start State: _________
    b. Stop State: _________
2. Identify what the dog will be doing after each set of actions OR write **ERROR** if the set of actions is not valid.
    a. Doorbell, Tell to sit, Throw ball: _________
    b. Tell to sit, Doorbell, Tell to sit: _________
    c. Tell to sit, Throw ball, Tell to Lay: _________
    d. Tell to sit, Throw ball, Throw ball: _________
    e. Doorbell, Tell to sit, Doorbell, Throw ball, Tell to sit: _________
3. Circle the paths from question 2 where the dog barks.

APPENDIX O: FINITE STATE AUTOMATA ASSESSMENT RUBRIC

FSA Worksheets

	3 Proficient	2 Partially Proficient	1 Unsatisfactory
Robot Dog Transition	Student is able to clearly identify the final state (or Error) for each set of instructions	Student is able identify some (3+) but incorrectly answers, and/or misses error sets.	Student does not answer properly.
State Selection	Student identifies Barking states	Student identifies at least one barking state.	Student does not attempt or circles incorrect sequences
Finite State Construction	Student is able to represent a Chores Robot using FSA symbols (states, transition, start, stop). Transitions clearly show direction.	Student is able to partially model Chores Robot using FSA symbols. Direction of transition is not clear, Not complete or multiple versions of states	Student is unable to represent the relationship between the selected states using transitions.
Chores Robot Transitions	Student labels 2 paths that hit every state at least once, with no errors	Students only creates one correct set of transitions	Student creates no correct sets of transitions

APPENDIX P: MINIMAL SPANNING TREES ASSESSMENT



APPENDIX Q: MINIMAL SPANNING TREES ASSESSMENT RUBRIC

Minimal Spanning Tree

	3 Proficient	2 Partially Proficient	1 Unsatisfactory
Halloween Candy	Student is able to correctly complete the MST	Student has one or two missing or incorrect lines. Student has more than 9 Lines	Student has more than 9 lines, or does not have them all connected. Has more than 3 incorrect lines

ASCII: Storing Letters as Numbers

ASCII stands for the American Standard Code for Information Interchange. It's a system used to represent English characters, and it was designed to encode 128 different characters. The table below maps the uppercase alphabet to 7-digit values.

A 1000 001	B 1000 010	C 1000 011	D 1000 100	E 1000 101	F 1000 110
G 1000 111	H 1001 000	I 1001 001	J 1001 010	K 1001 011	L 1001 100
M 1001 101	N 1001 110	O 1001 111	P 1010 000	Q 1010 001	R 1010 010
S 1010 011	T 1010 100	U 1010 101	V 1010 110		
W 1010 111	X 1011 000	Y 1011 001	Z 1011 010		

Part I. First try translating this message from binary numbers to English letters:

1000 010 1000 101 1000 111 1001 001 1001 110

When saving data to your computer or sending data over the internet, errors can happen. The character "A" is the number 65 in binary. The number 65 only takes seven bits to represent, and the eighth bit is used as a *parity* bit to try and detect if an error happened while saving the letter to your computer.

A: 1000001 **0**

Binary for "65" 0 is the *parity* bit

Below is part of the ASCII table (the part that shows capital letters) with parity bit shown in **bold**:

A 1000 001**0**	B 1000 010**0**	C 1000 011**1**	D 1000 100**0**	E 1000 101**1**	F 1000 110**1**
G 1000 111**0**	H 1001 000**0**	I 1001 001**1**	J 1001 010**1**	K 1001 011**0**	L 1001 100**1**
M 1001 101**0**	N 1001 110**0**	O 1001 111**1**	P 1010 000**0**	Q 1010 001**1**	R 1010 010**1**
S 1010 011**0**	T 1010 100**1**	U 1010 101**0**	V 1010 110**0**		

Part II. Complete the table by filling in the parity bit for the letters W,X,Y and Z. **Remember that a parity bit is 0 if there are an *even* number of 1's in the binary number, or it is 1 if there are an *odd* number of 1's in the binary number.**

W 1010 111		X 1011 000		Y 1011 001		Z 1011 010	

Part III. Below is the same message, but this time it was sent with parity bits. Is there an error in the message? **Circle a binary number if you think it was sent incorrectly.**

1000 0100 1000 1011 1000 1110 1001 0010 1001 1100

If you finish early, try writing a message using ASCII below.

APPENDIX S: PARITY AND ERROR DETECTION ASSESSMENT RUBRIC

Error Detection Worksheets

	3 Proficient	2 Partially Proficient	1 Unsatisfactory
Data Representation	Student uses the given letter mapping and translates from binary numbers to characters with no errors.	Student uses the given letter mapping, and converts most numbers correctly (only one error).	Student is unable to decode 7-bit ASCII values using a given ASCII table and message.
Parity Bits (1D)	Student correctly computes the parity bits for letters in the ASCII table.	Student partially completes the parity bits for the ASCII table, or has some incorrect parity bits.	Student does not attempt to add parity bits to the ASCII table.
Error Detection (1D)	Student correctly identifies the fourth letter to have been sent with an error, and is able to justify why it cannot be corrected.	Student identifies two or more letters containing an error, is unable to justify why the error cannot be corrected. OR Student is able to justify why the error cannot be corrected, but does not identify the correct letter.	Student identifies no letters containing an error (or possibly did not attempt).

DRAGONS VS. COWS: DAFFODAI

Day 1:

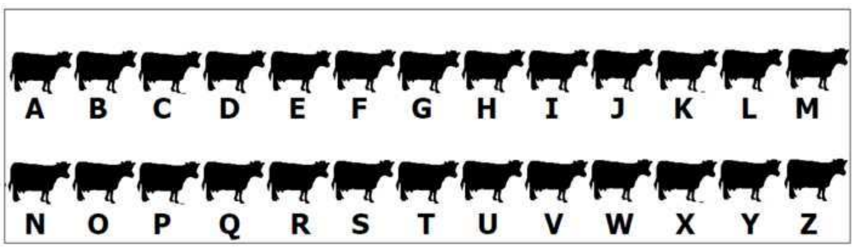
Dragons have invaded your kingdom, Daffodai. Your livestock were lazily grazing in the pasture *when one cow was suddenly attacked by a dragon***.** An observant neighbor said that they saw the **dragon attacking the cow that weighs 7621 pounds** but was unsure which cow it was. To find the cow that is being attacked, you must question your neighbor who is currently holding the Day 1 cow records.

The records show a letter that represents each cow as well as each cow's weight. The records are not in any sort of order.

Instructions:

To find the dragon as quickly as possible, **guess which cow (letter) the dragon is attacking** and your partner who represents the "neighbor" will tell you the weight of that cow. Record your guesses in the table below. **If you can find the dragon in 10 guesses or less, you can save all the cows!**

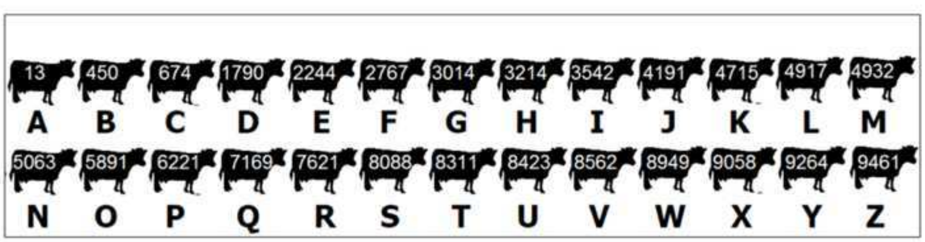
Keep track of your guesses by crossing out cows as you go. Number of Guesses: ______



Guess #	Cow								
1		7		13		19		25	
2		8		14		20		26	
3		9		15		21			
4		10		16		22			
5		11		17		23			
6		12		18		24			

Day 2:

Ordered List of Cows



APPENDIX U: SEARCHING ASSESSMENT RUBRIC

Searching Worksheets

	3 Proficient	2 Partially Proficient	1 Unsatisfactory
Searching: Application	Student uses an appropriate searching algorithm (binary search) to discover the cow in question. Cows are marked to show which ones have been queried.	Student clearly tries to use a binary search but not 100% correct.	Student searches randomly, does not search for the cow or does not mark the cows on the searching worksheet.

Notes:
Students with the unsorted list are not graded, and instead just tally the total number who used a searching algorithm, and those who did not.

APPENDIX V: FINAL PROJECT RUBRIC

Pre/Post Project

	3 Proficient	2 Partially Proficient	1 Unsatisfactory
Minimal Spanning Tree (ants & planes)	Student constructs a minimal spanning tree (see answer key) to connect all the cities	Student creates a minimal spanning tree with 2 errors	Student does not connect all the cities OR Student has more than 2 paths that are wrong OR Student adds in edges not present in the original graph
MST (post only)	Student knows the number of required tracks	Number of tracks is off by 1	Number of tracks is blank or incorrect
FSA Part 1	Student is able to create a correct FSA	Student uses some of the boldface states and attempts to connect them using a discernable flow. There are no forks (i.e. they simply create one possible schedule) or start/stop states, so the diagram resembles a linked list.	Student uses the numbered sentences (each containing multiple states) as their states OR Student does not use any boldface states OR Student does not attempt
FSA Part 2	Student correctly identifies two valid schedules	Student is only able to find one valid schedule	Student identifies the invalid option as the only good schedule OR finds no valid schedules
Numbers & Symbols: Data Representation	Student demonstrates ability to convert between number systems and represent numbers as letters by correctly decoding the message to be “SEVEN” or ‘EIGHT” (	Student correctly identifies some of the letters	Student is unable to recognize pattern for binary numbers and cannot convert numbers to letters or does not attempt the problem.
Searching	Student gives an answer that can be reasoned to be binary search	Student gives an answer between that is off by 1	Student is off by more than 1
Who Did It	Student identifies murderer/ misbehaving pet		Student does not identify. Keep a count of how many students get each answer.
Extra	Student correctly identifies all 6 numbers/locations	Student correctly identifies at least 3 numbers	Student did not attempt or has clearly incorrect answers

APPENDIX W: CS UNPLUGGED TODO LIST

Activity	Suggested Modifications
Artificial Intelligence	Create clearer introduction to the Turing Test
Binary Numbers	N/A
Computer Vision	Create less tedious worksheets
Cryptography	Create a more in-depth introduction and background to Cryptography.
Deadlock and Routing	Create a more technical explanation of
Finite State Automata	Simplify kinesthetic activity, revise lecture
Image Representation	N/A
Minimal Spanning Trees	Reinforce Kruskal's algorithm
Parity and Error Detection	Supply more concrete real-world connection
Searching	Revise entire curriculum
Sorting	Revise entire curriculum
General	Improve videos, add teacher-specific assessments