To solve a Rubik’s Cube, you first need to get to know the it. What are all those colored tiles about? How do they move? How do you know when the Rubik’s Cube is solved? Then you need to think about what it is you need to do to solve it. You’re probably thinking you’ll get one face the same color first, then another, and another, until each face of the Rubik’s Cube is a solid color. This approach to solving the Rubik’s Cube is much like thinking about a problem you’d like to have a computer solve.

In this lesson, gr 5 - 9 students learn to solve the first 2 stages of solving a Rubik’s Cube as they learn the concepts and process of coding. They will write, test, and refine algorithms to make the WHITE face (and the beginnings of the lateral faces) of the Rubik’s Cube. The lessons could be modified for older or younger students. The pages that follow are organized as student handout pages which guide them through the solving/coding process followed by teacher pages with answer keys and some additional suggestions for the lessons.

Standards Addressed in this Lesson: (https://www.iste.org/standards/for-students)

**Innovative Designer**
Students use a variety of technologies within a design process to identify and solve problems by creating new, useful or imaginative solutions.

- 4a Students know and use a deliberate design process for generating ideas, testing theories, creating innovative artifacts or solving authentic problems.
- 4c Students develop, test and refine prototypes as part of a cyclical design process.
- 4d Students exhibit a tolerance for ambiguity, perseverance and the capacity to work with open-ended problems.

**Computational Thinker**
Students develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions.

- 5a Students formulate problem definitions suited for technology-assisted methods such as data analysis, abstract models and algorithmic thinking in exploring and finding solutions.
- 5c Students break problems into component parts, extract key information, and develop descriptive models to understand complex systems or facilitate problem-solving.
- 5d Students understand how automation works and use algorithmic thinking to develop a sequence of steps to create and test automated solutions.

**Materials:**

- Rubik’s® Cube for each student
- *You CAN Do the Rubik’s Cube* solution guide for each student (optional)
- handout for each student or group
- red, green, blue, yellow, orange colored pencils, markers, or crayons
- easily removable small sticker or a dry erase marker
- journal for each student/team (If each student has a handout, that might also serve as the student’s journal.)
- access to a computer and Scratch [https://scratch.mit.edu](https://scratch.mit.edu)
Background knowledge:
Students need no knowledge of a Rubik’s Cube or how to solve it. However, the Teacher/Facilitator of the lesson may find it helpful to review the “Get to Know Your Rubik’s Cube” Teacher Guide which can be downloaded at no cost at https://www.youcandothecube.com/educators/teach-to-solve/.

Students should be able to:
- identify the face of a Rubik’s Cube
- make 90º and 180º turns

Here is a suggested timeline for these lessons:

<table>
<thead>
<tr>
<th>Lesson title</th>
<th>page</th>
<th>time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Getting to Know the Rubik's Cube</td>
<td>p 3 - 8</td>
<td>1 day</td>
</tr>
<tr>
<td>Making the Daisy</td>
<td>p 9 - 12</td>
<td>1-2 days</td>
</tr>
<tr>
<td>Coding the Daisy</td>
<td>p 13 - 21</td>
<td>2-3 days</td>
</tr>
<tr>
<td>Solving the WHITE Cross</td>
<td>p 22 - 25</td>
<td>1-2 days</td>
</tr>
<tr>
<td>Coding the WHITE Cross</td>
<td>p 26 - 27</td>
<td>1-2 days</td>
</tr>
<tr>
<td>Solving the WHITE Corners</td>
<td>p 28 - 31</td>
<td>1-2 days</td>
</tr>
<tr>
<td>Coding the WHITE Corners</td>
<td>p 32 - 35</td>
<td>2-3 days</td>
</tr>
<tr>
<td>Next Steps</td>
<td>p 36 - 37</td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td>p 38</td>
<td>Teacher page</td>
</tr>
<tr>
<td>Appendix A Steps to Problem Solving</td>
<td>p 39</td>
<td></td>
</tr>
<tr>
<td>Appendix B Turn Cards</td>
<td>p 40</td>
<td></td>
</tr>
<tr>
<td>Appendix C Rubik’s Cube Planning Sheet</td>
<td>p 41</td>
<td>Student Worksheet</td>
</tr>
</tbody>
</table>

Thanks to Kathy Talbot, Instructional Technology Specialist, for her contributions to this unit.
When you are solving a difficult problem, re-ask the problem so that your solution helps you learn faster.

Aza Raskin You Are Solving The Wrong Problem, UX Magazine, Article No: 663 | May 2, 2011

So what is the problem you are trying to solve? Like millions of people around the world, you are trying to solve a Rubik’s Cube! That’s a difficult problem! So how do you “re-ask the problem so that your solution helps you learn faster”?

Throughout this unit, we’ll use a four step process to help come up with a solution for this problem. The steps are Define, Prepare, Try, and Reflect.

Define: Before you define the problem of solving the Rubik’s Cube, it will be helpful to understand the characteristics of the Rubik’s Cube and how it moves.

What colors are on the Rubik’s Cube?

How are they arranged on the Rubik’s Cube?

One of the tiles tells you what color the face of a solved Rubik’s Cube will be. Compare the scrambled Rubik’s Cube on the left to the solved Rubik’s Cube on the right above. Which tile tells you what color the face of a solved Rubik’s Cube should be?
When you are solving a difficult problem, re-ask the problem so that your solution helps you learn faster.

Aza Raskin You Are Solving The Wrong Problem, UX Magazine, Article No :663 | May 2, 2011

This article is worth sharing with you students. There are some great examples of famous inventions that were solved by reframing the questions and by learning from failures.

So what is the problem you are trying to solve? Like millions of people around the world, you are trying to solve a Rubik's Cube! That’s a difficult problem! So how do you “re-ask the problem so that your solution helps you learn faster?”

Throughout this unit, we’ll use a four step process to help come up with a solution for this problem. The steps are Define, Prepare, Try, and Reflect. The steps to problem solving are based on the Polya model. See Appendix A.

○ Define: Without defining a problem, you might solve the wrong problem, not know where to start, or not know when you’re finished. Do you have all the information you need? Keep a list of new discoveries and questions along the way.

○ Prepare: Develop a plan with a team or partner. Include diagrams where possible. Even well-defined problems usually have many possible approaches. Make each try more likely to succeed by first examining your options and anticipating challenges. Patience and persistence is important to see your plan through.

○ Try: It's important to be persistent and patient so long as your plan still may work. Make notes along the way of small discoveries or questions that come up.

○ Reflect: You'll likely not solve the problem the first time or there will be a better way to solve it. Learn from your past attempts and get ready to start the process again. If your plan is not working, consider some of your other options. Notes you’ve made along the way will be valuable.

Define: Before you define the problem of solving the Rubik's Cube, it will be helpful to understand the characteristics of the Rubik's Cube and how it moves.

What colors are on the Rubik's Cube? White, red, blue, orange, green, yellow

How are they arranged on the Rubik's Cube? White is opposite yellow; orange, opposite red; blue, opposite green. If you hold the Rubik's Cube with white on top and blue facing you, red will be on the left face, orange on the right.

How do you tell what color a face should be on a scrambled cube? The center tile on each face determines the color of the face when the Rubik's Cube is solved.
Everyone has some type of language to communicate. Computers also use languages to communicate and, like human languages, they have specific vocabulary words known as **commands**. The Rubik’s Cube also has a “language” or set of commands to communicate what to do to solve it.

Each turn in Rubik’s language is a ¼ or $90^\circ$ turn. If you are looking at the face you are turning, the turn is clockwise.

When an **apostrophe (’)** follows a command, it means to turn in the opposite direction. This is a counterclockwise turn if you were looking at the face you are turning. To keep things simple, just follow the arrows!
Everyone has some type of language to communicate. Computers also use languages to communicate and, like human languages, they have specific vocabulary words known as **commands**. The Rubik’s Cube also has a “language” or set of commands to communicate what to do to solve it. There is no attempt in this lesson to write code that would create a Rubik’s Cube which can be solved. Rather, students are introduced to some basic coding concepts using Scratch, a free coding language, to illustrate them. [https://scratch.mit.edu/](https://scratch.mit.edu/) There are several Rubik’s Cube projects in the Scratch library which may be “remixed” (copied and edited in Scratch talk). You can find them by typing Rubik’s Cube in the search window. One example is [https://scratch.mit.edu/projects/11515292](https://scratch.mit.edu/projects/11515292), Playable Rubik’s Cube, created by boaz4.

Appendix C has this set of commands that could be duplicated and used as a set of cards that students could physically manipulate as they write their instructions or code.

Each turn in Rubik’s language is a ¼ or 90° turn. If you are looking at the face you are turning, the turn is clockwise.

When an **apostrophe (‘)** follows a command, it means to turn in the opposite direction. This is a counterclockwise turn if you were looking at the face you are turning.

To keep things simple, just follow the arrows!

These commands are universally used by those who solve the Rubik’s Cube. It may be helpful to make sure that students understand some of the other vocabulary of the Rubik’s Cube.

- **Layers vs faces**
- **Hints for turns** (i.e. U turns may be better remembered if they are associated with opening and closing a jar)

These and other suggestions may be found in “Get to Know Your Rubik’s Cube” lesson of the You CAN Learn to Solve Teacher Guide. [https://www.youcandothecube.com/educators/teach-to-solve/](https://www.youcandothecube.com/educators/teach-to-solve/)
Using a small sticker or dry erase marker, mark one of the tiles on the Rubik's Cube. Notice where it goes as you turn and twist the Rubik's Cube. Record your moves and where the X is on the Rubik's Cube on the tracking sheet.

Here are two examples of how to track the movement of a tile. Using the Track the Rubik's Cube sheet, color the Center tiles for the front, top, and right faces. In the examples, they are red, blue, and white. Then, mark the tile you want to track. In the examples, there is an X on the red tile we are tracking.

Example 1:

Example 2:

Use the Rubik's Cube planning sheet to learn more about where tiles go when you make turns on the Rubik's Cube.
Using a small sticker or dry erase marker, mark one of the tiles on the Rubik's Cube. Notice where it goes as you turn and twist the Rubik's Cube. Record your moves and where the X is on the Rubik's Cube on the tracking sheet.

Here are two examples of how to track the movement of a tile. Using the Track the Rubik's Cube sheet, color the Center tiles for the front, top, and right faces. In the examples, they are red, blue, and white. Then, mark the tile you want to track. In the examples, there is an X on the red tile we are tracking. **Students will sometimes need to color the Center tiles on the back, left, and down faces in order to see where the marked tile has traveled.**

Example 1:

![Example 1](up-front-right-center-red-blue-white.png)

The RED Center will always be on the front.

Made this turn: \( R \)

Then made this turn: \( U' \)

Then made this turn: \( B \)

Since you can't see the X from the front view, you need to color the Center tiles on the other views.

Example 2:

![Example 2](up-front-right-center-red-blue-white.png)

The RED Center will always be on the front.

Made these turns: \( F \ R' \ U' \)

\((R' \ & \ U' \ did \ not \ move \ the \ X.)\)

Then made these turns: \( F' \ L' \)

Then made these turns: \( U \ B \)

Since you can't see the X from the front view, you need to color the Center tiles on the other views.

Use the Rubik's Cube planning sheet to learn more about where tiles go when you make turns on the Rubik's Cube. *(Found in Appendix B)*

As students perform this exploration, help them to see that keeping the same face UP will make it easier to track and record. Suggest keeping the Rubik's Cube on the desk and/or putting a sticker on each center tile to mark its position - U(p), F(ront), L(eft), R(ight), B(ack), D(own). Make sure that all sticker residue is completely removed, especially from YCDTRC borrowed Rubik's Cubes. A dry erase marker may also work.
When you are solving a difficult problem, re-ask the problem so that your solution helps you learn faster.

Aza Raskin  You Are Solving The Wrong Problem, UX Magazine, Article No :663 | May 2, 2011

Prepare: We started by saying our problem was to solve a Rubik’s Cube. But since this is a difficult problem, we’re going to re-ask the question so we can learn faster. Most people solve the Rubik's Cube by making a WHITE Cross first. Making a WHITE Cross has 2 stages. The first is to make a daisy on a face of the Rubik's Cube.

What would a Daisy look like on a face of a Rubik’s Cube? Use the grid below to draw/color your goal. Mark any white squares with W.

What pieces of the Rubik's Cube will be involved? Circle these pieces in your drawing.
When you are solving a difficult problem, re-ask the problem so that your solution helps you learn faster.

Aza Raskin You Are Solving The Wrong Problem, UX Magazine, Article No :663 | May 2, 2011

**Prepare:** We started by saying our problem was to solve a Rubik’s Cube. But since this is a difficult problem, we’re going to re-ask the question so we can learn faster. Most people solve the Rubik’s Cube by making a WHITE Cross first. Making a WHITE Cross has 2 stages. The first is to make a daisy on a face of the Rubik’s Cube.

Since you are making the Daisy first, what will that face look like when it’s done? Use the grid below to draw/color your goal. Mark any white squares with W.

The YCDTRC guide makes the Daisy as the first step to solving the WHITE Cross. Note that only the Center tile and the Edge pieces matter. The Corners can be any color.

<table>
<thead>
<tr>
<th>Doesn’t matter</th>
<th>W</th>
<th>Doesn’t matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td></td>
<td>W</td>
</tr>
<tr>
<td>Doesn’t matter</td>
<td>W</td>
<td>Doesn’t matter</td>
</tr>
</tbody>
</table>

What pieces of the Rubik’s Cube will be involved? Circle these pieces in your drawing. (see above)
**Try:** Make a Daisy on a face of a Rubik’s Cube. What will you need to do to make it?

It may help to answer these questions first.

On what color face will you make the Daisy? Does it matter? Consult your drawing.

Where will that color be facing as you work the Rubik’s Cube? (UP face, DOWN, FRONT, BACK, LEFT, or RIGHT)

What **commands** will you use to communicate the moves to a person or machine trying to duplicate your results? Using the Rubik’s Cube language, write or list the **commands** (list of moves) you used to make the Daisy. You may need to use additional non-Rubik’s words to make the instructions clear. For example, you might write “Hold the Rubik's Cube so the RED face is on the left.” so the solver knows how to hold the Rubik’s Cube.

**Reflect:** Look over your notes from your attempt(s) in solving and coding the Daisy.

What made you curious today?

What did you learn about the Rubik’s Cube?

Where did you encounter struggle today and what did you do to deal with it?

What about your thinking, learning, or work today brought you the most satisfaction? Why?
Try: Make a Daisy on a face of a Rubik's Cube. What will you need to do to make it?
The comments, hints, and sample code provided in this lesson will follow the You CAN Do the Rubik's Cube Solution Guide. In the guide, we make the Daisy as an intermediary step for making the WHITE Cross. It may help to answer these questions first.

On which face will you make the Cross? Does it matter? Consult your drawing.
The Daisy will be made on the YELLOW face so that the Center of the Daisy is YELLOW.
Where will that color be facing as you work the Rubik's Cube? (UP face, DOWN, FRONT, BACK, LEFT, or RIGHT)
We recommend that the Daisy be created on the UP face. At this point, it probably doesn’t matter but as one moves further into solving the Rubik's Cube, how one holds the Rubik's Cube is crucial.

What commands will you use to communicate the moves to a person or machine trying to duplicate your results? Using the Rubik's Cube language, write or list the commands (list of moves) you used to make the Daisy. You may need to use additional non-Rubik's words to make the instructions clear. For example, you might write “Hold the Rubik's Cube so the RED face is on the left.” so the solver knows how to hold the Rubik's Cube.

Reflect: Look over your notes from your attempt(s) in solving and coding the Daisy.

What made you curious today?
What did you learn about the Rubik's Cube?
Where did you encounter struggle today, and what did you do to deal with it?
What about your thinking, learning, or work today brought you the most satisfaction? Why?

Most students are able to create the Daisy with little direct instruction. You might have them go back to the Tracking the Rubik's Cube activity to help them gain further insights into the workings of the Rubik's Cube. Since there are many ways to hold the Rubik's Cube and 12 locations where the “petals” of the Daisy could be, this is a complicated task to write out step by step. It may take several edits before students have a clear set of directions. Working with a partner or in small groups is suggested.

However, if students are feeling frustrated, you might share the video for Layer 1 Step 1: Create a Daisy on the You CAN Do the Rubik's Cube Teaching to Solve page (https://www.youcandothecube.com/educators/teach-to-solve/) so that students might get some insights. For those who need more direction, the PowerPoint presentation on that page or the You CAN Do the Rubik’s Cube Solution Guide (https://www.youcandothecube.com/solve-the-cube/) are both resources which provide step by step directions for making the Daisy.

www.youcandothecube.com has both online and downloadable solution guides. There are also videos on the site. YouTube has a vast selection of videos on solving the Rubik's Cube. However, there is much to be gained from playing with the Rubik’s Cube before consulting these resources.
When you are solving a difficult problem, re-ask the problem so that your solution helps you learn faster.

Aza Raskin You Are Solving The Wrong Problem, UX Magazine, Article No :663 | May 2, 2011

Define: Now you are going to take your commands for making the Daisy on a Rubik’s Cube and rewrite them for a computer to follow. As you may know, computers have their own languages just as people do. This process is called coding.

Look at your commands. Are there any moves that get repeated? In computer languages, this is called a loop block. Are there some moves that get done only if there is a certain situation? In computer languages, this is called a conditional block. Having a set of commands in a block makes your code shorter or more concise. It also makes your code more efficient. Here are some blocks from the computer language Scratch:

What do you think each one does?
When you are solving a difficult problem, re-ask the problem so that your solution helps you learn faster.

Aza Raskin You Are Solving The Wrong Problem, UX Magazine, Article No :663 | May 2, 2011

Define: Now you are going to take your written directions for making the Daisy on a Rubik’s Cube and rewrite them for a computer to follow. As you may know, computers have their own languages just as people do. This process is called coding.

Look at your commands. Are there any moves that get repeated? In computer languages, this is called a loop block. Are there some moves that get done only if there is a certain situation? In computer languages, this is called a conditional block. Having a set of commands in a block makes your code shorter or more concise. It also makes your code more efficient. Here are some blocks from the computer language Scratch:

What do you think each one does?

It is important that students recognize the differences among these 3 blocks.

The repeat block carries out the steps inside the block, in the order in which they are listed, for as many times as indicated in the circle (10 times in this example). You may want to emphasize the arrow at the bottom right of the block indicating the repetition. This block is not dependent on the outcome.

The repeat until block carries out the steps inside the block, in the order in which they are listed, until a specified condition is met. You may want to emphasize the arrow at the bottom right of the block. This block is not dependent on the outcome. This block is dependent on the outcome.

The if..then block executes the steps inside the block once, in the order in which they are listed, only if the specified condition is met. Have students note that there is no arrow at the bottom of this block. This block may not be executed and is not dependent on the outcome.

At this time, the syntax of the blocks does not matter. Students may describe the condition in a way that makes sense to them and others using their “code” or sequence of steps.
Can you follow this Scratch code to move around the room?

In this Scratch code, the commands are written in blue and the blocks in gold. There is a **repeat block** with a **conditional block** nested inside it. With a partner, take turns following the code and see where it takes you. Did you and your partner get the same results?
Can you follow this Scratch code to move around the room?

In this Scratch code, the commands are written in blue and the blocks in gold. There is a **repeat block** with a **conditional block** nested inside it. With a partner, take turns following the code. Did you and your partner get the same results?

Students will physically execute this Scratch"ish" program to learn about nested commands. Make sure students see which commands are within the blocks and which are not. Students may have different results because they have started in different places in the room and may or may not have obstacles in their paths.

We recognize that this is not actual Scratch code. The objective of this lesson is to introduce beginning coders to the concepts of coding. To build that understanding, we have taken liberties with the commands and in defining the block conditions and syntax.
Try: Now that you know a little about blocks in the Scratch computer language, how might you use them to code your commands for making a Daisy on a Rubik’s Cube? Look at the commands you wrote. Can you identify which Scratch blocks you might need?

These questions might help you.

- Are there steps that get repeated? If so, circle them in your commands.
- Are there conditional steps that are made only when something else happens? Highlight those.

Using the Scratch blocks, write the code that uses your list of commands to make the Daisy.

Have a classmate try to make the Daisy following your code. Edit your code for clarity as you execute it. Make notes of what seems to work and what doesn’t.
Try:  Now that you know a little about blocks in the Scratch computer language, how might you use them to code your commands for making a daisy on a Rubik’s Cube? Look at the commands you wrote. Can you identify which Scratch blocks you might need?

These questions might help you.

- Are there steps that get repeated? If so, circle them in your commands.
- Are there conditional steps that are made only when something else happens? Highlight those.

Using the Scratch blocks, write the code that uses your list of commands to make the Daisy.

This is one possible code for making the Daisy. Note that the code has some commands, such as “hold the Rubik’s Cube so…”, that are not in the Rubik’s language but must be included if one is to successfully solve the Rubik’s Cube. The Scratch code* follows on the next page.

Hold YELLOW Center tile on UP face
Repeat until all the UP Edges are WHITE tiles
  Locate an Edge piece not on the UP face that has a WHITE tile
    If the WHITE tile is on the DOWN face then
      Look to see where the tile will go if you move it to the UP
      Repeat until there isn’t a WHITE tile there
    Else
      Turn the face 180º so that the WHITE tile is on the UP face
  Else
    Hold the Rubik’s Cube so the WHITE tile is on the FRONT face
      If the WHITE tile is top or bottom layer of the FRONT face then
        Look to see where the tile will go if you move it to the UP
        Repeat until there isn’t a WHITE tile there
    Else
      If the WHITE tile is left side of the FRONT face then
        Else

*We recognize that this is not actual Scratch code. The objective of this lesson is to introduce beginning coders to the concepts of coding. To build that understanding, we have taken liberties with the commands and in defining the block conditions.
Possible Scratch code for making the Daisy.

1. Hold the Cube so the YELLOW Center is on the UP face.
2. Repeat until all the UP Edges are WHITE tiles.
   - Locate an Edge piece not on the UP face that has a WHITE tile.
   - If the WHITE tile is on the DOWN face then:
     - Look to see where the tile will go if you move it to the UP Face.
     - Repeat until there isn't a WHITE tile there.
   - Turn the face 180° so the WHITE tile is on the UP face.

3. Hold the Cube so the WHITE tile is on the UP face.
4. If the WHITE tile is on Top or Bottom layer of the FRONT face then:
   - Turn 90 degrees.
   - Look to see where the tile will go if you move it to the UP face.
   - Repeat until there isn't a WHITE tile there.
5. If the WHITE tile is left side of the FRONT face then:
   - Turn 90 degrees.
6. Else:
   - Turn 90 degrees.
**Reflect:** Look over your notes from your attempt(s).

What did you learn about coding in Scratch?

Think about your commands. What happened when you followed your commands? Is there something you could do differently?

It often takes many edits to write efficient code. Re-frame your commands to make them more efficient. Here are some things you can try to improve your code.

- Look over your code for commands that are repeated. Can you use repeat blocks?
- Try changing the order of the commands.
  - Do you get the same results?
  - Are there commands you can eliminate now?
Reflect: Look over your notes from your attempt(s).

What did you learn about coding in Scratch?

Think about your commands. What happened when you followed your commands?

Is there something you could do differently?

It often takes many edits to write efficient code. Re-frame your commands to make them more efficient. Here are some things you can try to improve your code.

- Look over your code for commands that are repeated. Can you use repeat blocks?
- Try changing the order of the commands.
  - Do you get the same results?
  - Are there commands you can eliminate now?

As with the written instructions, coding the Daisy can be a complicated process with many conditional blocks. Have students play with the order of the conditions as it may help them to see how to simplify the code. It may make it easier to manipulate the order of the code if the most nested blocks are written on index cards.

While not technically computer-ready code, the “repeat until” conditions specified in this code allow for some wiggle room for beginning coders. The objective is to introduce students to the concepts of coding, not actually have a computer execute the code at this time.
**Cracking the Code: Solving a Rubik's Cube - Solving the WHITE Cross**

*When you are solving a difficult problem, re-ask the problem so that your solution helps you learn faster.*

Aza Raskin *You Are Solving The Wrong Problem*, *UX Magazine*, Article No :663 | May 2, 2011

Does your Rubik's Cube look like this? The tiles that are grey can be any color.

YEAH! You have created the Daisy, the first part in solving the WHITE Cross. Now on to part 2 of solving the WHITE Cross.

**Define:** To complete the WHITE Cross, you'll need to have a WHITE tile instead of YELLOW in the Center. AND… you’ll need to match the color of the side of each Edge piece to a Center tile. The Rubik's Cube will look like this when you are done.

To help achieve this goal, let's take another look at how the Rubik's Cube is designed.

How do you know what color a side of the Rubik's Cube is supposed to be when it’s solved? We’ve asked this question before but it is worth revisiting this idea again here.

Identify the color of the sides and the color of each side’s opposite.

________________ is opposite _________________
________________ is opposite _________________
________________ is opposite _________________
________________ is opposite _________________

How does this information help you turn the Daisy into the WHITE Cross?

How does this information help you match the Edge tiles of the Daisy to Centers that are the same color?
When you are solving a difficult problem, re-ask the problem so that your solution helps you learn faster.

Aza Raskin You Are Solving The Wrong Problem, UX Magazine, Article No :663 | May 2, 2011

Does your Rubik’s Cube look like this? The tiles that are grey can be any color.

YEAH! You have created the Daisy, the first part in solving the WHITE Cross. Now on to part 2 of solving the WHITE Cross.

Define: To complete the WHITE Cross, you’ll need to have a WHITE tile instead of YELLOW in the Center. AND… you’ll need to match the color of the side of each Edge piece to a Center tile. The Rubik’s Cube will look like this when you are done.

To help achieve this goal, let’s take another look at how the Rubik’s Cube is designed.

How do you know what color a side of the Rubik’s Cube is supposed to be when it’s solved? We’ve asked this question before but it is worth revisiting this idea again here.

The Center tile on each face determines the color of that face.

Identify the color of each of the sides and the color of each side’s opposite.

_________ WHITE _______ is opposite _______ YELLOW _________

_________ RED _______ is opposite _______ ORANGE _________

_________ BLUE _______ is opposite _______ GREEN _________

How does this information help you turn the daisy into the WHITE Cross?
Since YELLOW is opposite WHITE, when the Daisy is on the UP face, each of the lateral faces will need to be turned 180° to make the WHITE Cross. However, students will need to match the non-WHITE Edge tiles to their respective Centers first.

How does this information help you match the Edge tiles of the daisy to Centers that are the same color? Knowing the opposites gives an awareness of how much and in which direction you’ll need to turn the UP face to match the non-WHITE Edge to the Center of the same color. This is not critical information at this time, but it can be helpful. For example, if the RED Edge tile is over the BLUE Center, you’ll need to turn the UP face 90° clockwise for the RED Edge to be over the RED Center. Later, when solving the Corners, knowing where the colors are relative to one another is more important.
PREPARE: We’ll need a new question to tackle. When you have solved the WHITE Cross, your Rubik’s Cube will look like this:

Notice that the RED tile of the WHITE-RED Edge piece is above the RED Center tile. The BLUE tile of the WHITE-BLUE Edge matches its BLUE Center.

How will you make the WHITE Cross and have the non-WHITE Edge tiles on the arms of the Cross match the color of the Center tile?

Here are a few hints:

- The petals of the daisy will become the arms of the WHITE Cross.
- You’ll first want to match the non-WHITE Edge tiles on the arms of the Daisy to the color of the Center tile. You’ll do one Edge at a time.

What moves will you make to match an Edge to its Center? Record any turns you make so that you can “undo” them to get back to the Daisy.

Once an Edge matches a Center, what moves will you make to make the WHITE Cross? (You’re adding the WHITE arms to the WHITE Center.) Record any turns you make so that you can “undo” them to get back to the Daisy.
PREPARE: We’ll need a new question to tackle. When you have solved the WHITE Cross, your Rubik’s Cube will look like this:

Notice that the RED tile of the WHITE-RED Edge piece is above the RED Center tile. The BLUE tile of the WHITE-BLUE Edge matches its BLUE Center.

How will you make the WHITE Cross and have the Edge tiles match the color of the Center tile?

Here are a few hints:

- The petals of the daisy will become the arms of the WHITE Cross.
- You’ll first want to match the non-WHITE Edge tiles on the arms of the Daisy to the color of the Center tile. You’ll do one Edge at a time.
- Students may become concerned that they are losing the Daisy. The Daisy was the first step in making the WHITE Cross. Remind them that the YELLOW Center means that side should be YELLOW, not WHITE, so the Daisy is not part of a solved Rubik’s Cube.

What moves will you make to match an Edge to its Center? Record any turns you make so that you can “undo” them to get back to the daisy.

Turn the UP face until a non-WHITE Edge tile matches its same color Center.

Once an Edge matches a Center, what moves will you make to make the WHITE Cross? (You’re adding the WHITE arms to the WHITE Center.) Record any turns you make so that you can “undo” them to get back to the Daisy.

Turn the face with the matching Edge and Center tiles 180°.
**TRY:** Write the code using your commands in the Scratch blocks that will move the petals of the Daisy to create the arms of the WHITE Cross.

**Reflect:** Look over your notes from your attempt(s).

Were there any unexpected results?

Were there any roadblocks? How did you move through roadblocks or challenges?

Is there a way to make your code more efficient?

  Remember, loop blocks are one way to make your code more efficient.
TRY: Write the Scratch code that will move the petals of the Daisy to create the arms of the WHITE Cross. Remember to use loop blocks to make your code efficient.

This is a possible code for creating the WHITE Cross from the Daisy.

Hold the Rubik’s Cube with the Daisy on the UP face
Repeat 4
  Hold the Rubik’s Cube so a WHITE Edge tile is on the FRONT UP face
  Repeat until the color of the non-WHITE Edge tile = color of the Center tile of the FRONT face
    U’
    F
    F

Possible Scratch code

Reflect: Look over your notes from your attempt(s).
Were there any unexpected results?

Were there any roadblocks? How did you move through roadblocks or challenges?

Is there a way to make your code more efficient?
  Remember, loop blocks are one way to make your code more efficient.

You may want to have students discuss why there is a repeat 4 in this code where all of the other repeat loops so far have been repeat until (condition is met). The commands inside the repeat 4 block are executed for each of the 4 petals of the Daisy.

We recognize that this is not actual Scratch code. The objective of this lesson is to introduce the concepts of coding to beginners. To build that understanding, we have taken liberties with the commands and in defining the block conditions.
When you are solving a difficult problem, re-ask the problem so that your solution helps you learn faster.

Aza Raskin You Are Solving The Wrong Problem, UX Magazine, Article No :663 | May 2, 2011

Congratulations! You’ve solved the first stage of the Rubik’s Cube - the WHITE Cross. Not only do you have the WHITE Cross, but the non-WHITE Edge tiles of the WHITE Cross match their Centers.

The next stage is to solve the WHITE Corners. When you are done, the UP face of the Rubik’s Cube will be completely WHITE and each of the faces connected to the WHITE face will have a short T that is the color of its face. (Remember, the color of each face is determined by the color of the Center tile.) So when you’ve solved the WHITE Cross, each of those faces will be almost halfway solved!

**Define:** There are a couple of things to think about when you solve the WHITE Corners. Maybe the first question you need to ask is “How do I move the Corners without losing the WHITE Cross?”

When you are solving the WHITE Corners, you want to make sure that you don’t “mess up” the WHITE Cross. Are there any single moves you can make that won’t lose the WHITE Cross? Record any turns you make so that you can “undo” them to get back to the WHITE Cross.

Now, experiment with temporarily moving the WHITE Cross using several turns in order to move any Corner to another position. At this point, you are not trying to get the WHITE Corners in the correct location. You are trying to move the Corners without losing the WHITE Cross. Remember - the non-WHITE Edge tiles must also match their Centers so you can’t lose that either.

Hold your Rubik’s Cube with the WHITE Cross on the UP face. Record any turns you make so that you can “undo” them to get back to the WHITE Cross.
When you are solving a difficult problem, re-ask the problem so that your solution helps you learn faster.

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The next stage is to solve the WHITE Corners. When you are done, the UP face of the Rubik’s Cube will be completely WHITE and each of the faces connected to the WHITE face will have a short T that is the color of its face. (*Remember, the color of each face is determined by the color of the Center tile.*) So when you’ve solved the WHITE Cross, each of those faces will be almost halfway solved!

**Define:** There are a couple of things to think about when you solve the WHITE Corners. Maybe the first question you need to ask is “How do I move the Corners without losing the WHITE Cross?”

Unlike the Daisy, the WHITE Cross is part of the solved Cube so you don’t want to lose it.

When you are solving the WHITE Corners, you want to make sure that you don’t “mess up” the WHITE Cross. Are there any single moves you can make that won’t lose the WHITE Cross? Record any turns you make so that you can “undo” them to get back to the WHITE Cross.

A U turn in either direction will move the WHITE Cross. However, the non-WHITE tiles on the Edge pieces will not longer match their Centers. So it might look like the WHITE Cross is correct but it is not. There are no single moves that move the Cross without losing the lateral Edge/Center alignment.

Now, experiment with temporarily moving the WHITE Cross using several turns in order to move any Corner to another position. At this point, you are not trying to get the WHITE Corners in the correct location. You are trying to move the Corners without losing the WHITE Cross. Remember - the non-WHITE Edge tiles must also match their Centers so you can’t lose that either.

Hold your Rubik’s Cube with the WHITE Cross on the UP face. Record any turns you make so that you can “undo” them to get back to the WHITE Cross.

Here is one way to move the corners without messing up the WHITE Cross. Hold your Rubik’s Cube with the WHITE Cross on the UP face. The following sequence will move the UP RIGHT corner to the BOTTOM. The WHITE Cross will be intact on the UP face when the sequence is completed.

You might provide this sequence to students and ask them how they might use it to move the Corners into the correct position. Have students analyze each step in the sequence following where the Corner pieces are going.

- **R’** moves the Corner to a different layer than the WHITE Cross but also messes up the WHITE Cross.
- **D’** moves the corner out of the way so that the **R** move restores the WHITE Cross.

Adding a **D** move to the sequence puts the moved corner under where it was initially but is not necessary..
If you have discovered a set of commands for moving Corners without losing the WHITE Cross, you are ready to think about the next step. Not only must the face be all WHITE, but the Corners need to be the correct position.

Look at the corners on the WHITE face of the Rubik's Cube on the left. The WHITE Corners are in the correct position. How do you know the corners are in the correct position? Maybe looking at the image on the right will help you decide.

Prepare: Look for a Corner piece on the bottom layer that has a WHITE tile. It does not matter what face the WHITE tile is on. Here are 3 examples.

If you don’t have a Corner piece with a WHITE tile on the bottom layer, think about the commands you used to move a Corner piece without changing the WHITE Cross. Use them to move a Corner piece to the bottom layer.

In the example above, the identified Corners are on the front right face of the Rubik’s Cube. The Corners are also below where they need to go. How would you know that?

If your Corner is not below where it needs to go, what commands will move it so that it is below where it needs to go?

What commands switch the Corner from the bottom layer to the top layer so that you can place the Corner in its correct location?

What commands place the Corner in its correct orientation, with each tile of the Corner piece matching its Center’s color?

Remember to hold your Rubik's Cube with the WHITE Cross on the UP face. Record any turns you make so that you can “undo” them to get back to the WHITE Cross if necessary. You will also need your written commands in order to write the code.
If you have discovered a set of commands for moving Corners without losing the WHITE Cross, you are ready to think about the next step. Not only must the face be all WHITE, but the Corners need to be in the correct position.

Have students execute this sequence of commands twice. The second iteration will put the Corner back where it was, although the orientation of the Corner will be different. Challenge them to repeat the sequence until the Corner is in its original orientation. This may give them insights for their code for placing the WHITE Corners.

Look at the corners on the WHITE face of the Rubik’s Cube on the left. The WHITE Corners are in the correct position. How do you know the corners are in the correct position? Maybe looking at the image on the right will help you decide.

The Corner is the correct position when the non-WHITE tiles match the Center tile of the face they are on. In the Rubik’s Cube on the right, the RED tiles on the top layer of the front, match the RED Center tile. The BLUE tiles on the top layer of the right face of the Rubik’s Cube match the BLUE Center on the right face. The non-WHITE tiles on the top layer of the Rubik’s Cube on the left do not match their respective Centers. The matching of the non-white tiles is important because the solved Rubik’s Cube will have solid color faces. By matching the Corner tiles, you have begun the process of solving the Rubik’s Cube by making each side a solid color. You might point out to students that the correctly solved corners make a short T on each of the lateral faces.

Prepare: Look for a Corner piece on the bottom layer that has a WHITE tile. It does not matter what face the WHITE tile is on. Here are 3 examples.

If you don’t have a Corner piece with a WHITE tile on the bottom layer, think about the commands you used to move a Corner piece without changing the WHITE Cross. Use them to move the Corner to the bottom layer.

R’, D’, R, D will move the Corner piece from the top layer to the bottom.

In the example above, the identified Corners are on the front right face of the Rubik’s Cube. The Corners are also below where they need to go. How do you know they are below where they need to go? In the examples above, the identified Corner is WHITE-BLUE-RED. The Corners are below where they need to go because they are the Corners between the RED and BLUE faces. When the Corner is in its correct location and orientation, the RED and BLUE tiles will match their respective Centers.

If your Corner is not below where it needs to go, what commands will move it so that it is below where it needs to go? D or D’ will move the mini-cubes on the bottom layer without moving any of the other layers.

What commands switch the Corner from the bottom layer to the top to place the Corner in its correct location?

R’, D’, R, D

What commands place the Corner in its correct orientation, with each tile of the Corner piece matching its Center’s color?

When the Corner is moved to the top layer, the WHITE tile may be on the Up face and the non-WHITE tiles of the Corner may match their respective Centers. If not, the student will continue to execute the R’, D’, R, D sequence until the Corners are in the correct location with the tiles match their respective Centers.
TRY: Write the code using your commands in the Scratch blocks that will correctly position the WHITE Corners on the Rubik's Cube.

Have a classmate try it. Edit your plan for clarity as you execute it. Make notes of what seems to work and what doesn't.

Reflect: Look over your notes from your attempt(s).

What surprised you about what you learned?

What lessons were learned from failure today?

What new information have you learned from this assignment?
Try:  Follow your plan to correctly position the WHITE Corners on the Rubik's Cube. Edit your plan for clarity as you execute it. Make notes of what seems to work and what doesn’t.

Sample code for WHITE Corners.

Repeat until the Corner tiles match the color of their respective Center tiles
  Locate a Corner piece with a WHITE tile.
  If the Center tiles of the located Corner do not match the color of their respective Centers
    Hold the Rubik's Cube so that the located corner is on the Front Right
    If the Corner is on the top layer then
      \( R' \)
      \( D' \)
      \( R \)

Repeat until the corner is between the faces that will be the same colors as the non-WHITE tiles

\( D \)

Repeat until the Corner tiles match the color of their respective Center tiles

\( R' \)
\( D' \)
\( R \)
\( D \)
Sample Scratch code for the WHITE Corners.

We recognize that this is not actual Scratch code. The objective of this lesson is to introduce the concepts of coding to beginners. To build that understanding, we have taken liberties with the commands and in defining the block conditions.

Repeat until the Center tiles match the color of their respective Centers

Locate a Corner piece with a WHITE tile

If the Center tiles of the located Corner do not match the color of their respective Centers then

Hold the Cube so that the located corner is on the Front Right

If the Corner is on the top layer then

Repeat until the Corner is between the faces that are the same colors as the non-WHITE tiles

Repeat until the Corner tiles match the color of their respective Center tiles
Have a classmate try it. Edit your plan for clarity as you execute it. Make notes of what seems to work and what doesn’t.

Depending on where your students are in their productive struggle of solving the WHITE Corners, you may want to share the algorithms in the Solution Guide, or the PowerPoint for Layer 1 Step 3: The WHITE Corners.

Reflect: Look over your notes from your attempt(s).

What surprised you about what you learned?

What lessons were learned from failure today?

What new information have you learned from this assignment?

The directions on ps.7-9 in the You CAN Do the Rubik’s Cube 2020 Solution Guide are different than the directions used in this lesson. This different approach to solving the WHITE Corners may jumpstart a discussion about coding for machines versus humans and/or about coding efficiently. In terms of both solving the Rubik’s Cube and in the furtherment of coding, it is important that students see both approaches.

Congratulations! While learning to solve half of the Rubik’s Cube, you’ve learned some very important life skills - perseverance through productive struggle and computational thinking. You have also gained an understanding of the basic structure of computer languages.

While Scratch and other block programming languages provide a good introduction to coding, they may not be the best language for more complicated tasks. In truth, the Scratch code in this lesson will not, by itself, solve the WHITE face. However, it did provide another way of communicating the algorithms to humans. There are quite a few Scratch projects which solve the Rubik’s Cube and are available to “remix”. Remix allows you to look at the code and modify it. You may want to explore some of these and compare the code to your own.

Or maybe you have some other problem you’d like to solve. Maybe you’d like to explore another computer language. Or maybe you want to finish solving the Rubik’s Cube. You will find the complete 3x3 Solution Guide at the end of this unit. Whatever path you choose, you’ve learned some valuable skills to help you tackle the next step.
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Or maybe you have some other problem you’d like to solve. Maybe you’d like to explore another computer language. Or maybe you want to finish solving the Rubik’s Cube. You will find the complete 3x3 Solution Guide at the end of this unit. Whatever path you choose, you’ve learned some valuable skills to help you tackle the next step.

As stated in the Student page, there are Scratch projects which solve the Rubik’s Cube. Comparing what students have done to the code in any one of those projects may be a good next step. There are several Rubik’s Cube projects in the Scratch library which may be “remixed” (copied and edited in Scratch talk). You can find them by typing Rubik’s Cube in the search window. One example is https://scratch.mit.edu/projects/11515292, Playable Rubik’s Cube, created by boaz4.

A completely different approach to coding the solution would be to number the tiles of the Rubik’s Cube in a 3 dimensional grid. Begin by looking at each face as a 2 dimensional array, which is a commonly used data structure in programming. Each tile can be represented as a (row, column) pair like this:

(1,1), (1,2), (1,3)
(2,1), (2,2), (2,3)
(3,1), (3,2), (3,3)

For forming the Daisy, (2,2), the Center tile, needs to be YELLOW. All other pairs, with a “2” in either position (row or column) need to be WHITE.

Along the same vein, each face can be assigned a number so that any tile on the whole Rubik’s Cube has an address in a 3 dimensional grid. The first digit in each triple is the color of the face. You might assign WHITE = 1, YELLOW = 2, and the other colors, 2 - 4 in order around the lateral faces. (1,1,1) would be the WHITE face, top row, first (or left corner) tile. (2,3,2) might be the BLUE face, bottom row, middle or edge tile.

Finally, you would still need to establish a rule for orienting the Rubik’s Cube so you know what color is in which position as you hold the Rubik’s Cube. For creating the Daisy, YELLOW would be the Up face and WHITE the DOWN face. The tile with coordinates (1, 2, 2) in the face shown above would be the Center tile on the WHITE face which when making the Daisy would be the DOWN face.

The code examples in these lessons could be modified to use this system of identifying specific tiles but is beyond the scope of this unit.
Learn to Solve the Rubik’s Cube
https://www.youcandothecube.com/
https://www.youcandothecube.com/educators/teach-to-solve/

Coding

Code.org, 1501 4th Ave, Suite 900, Seattle WA 98101
https://code.org/ Middle level Computer Science Discoveries

Usborne Publishing Ltd.

International Society for Technology in Education (ISTE), 1530 Wilson Boulevard, Suite 730
Arlington, VA 22209 https://www.iste.org/standards/for-students


Scratch
https://scratch.mit.edu

Reflection on One’s Learning

45 Awesome Must-Use Questions to Encourage Student Reflection and Growth
https://www.weareteachers.com/reflection-questions/

Ten Reflective Questions to Ask at the End of Class
http://www.brilliant-insane.com/2015/03/ten-reflective-questions-ask-end-class.html
Steps of the Problem Solving Process

○ **Define:** Without defining a problem, you might solve the wrong problem, not know where to start, or not know when you're finished. Do you have all the information you need? Keep a list of new discoveries and questions along the way.

○ **Prepare:** Develop a plan with a team or partner. Include diagrams where possible. Even well-defined problems usually have many possible approaches. Make each try more likely to succeed by first examining your options and anticipating challenges. Patience and persistence is important to see your plan through.

○ **Try:** It's important to be persistent and patient so long as your plan still may work. Make notes along the way of small discoveries or questions that come up.

○ **Reflect:** You'll likely not solve the problem the first time or there will be a better way to solve it. Learn from your past attempts and get ready to start the process again. If your plan is not working, consider some of your other options. Notes you've made along the way will be valuable.
Appendix B
Cracking the Code: Rubik’s Cube Commands

Make copies of this page and cut the images so that students have a set of cards to manipulate as they write their code.

- **R** clockwise 90° turn of RIGHT face
- **R’** counter-clockwise 90° turn of RIGHT face
- **L** clockwise 90° turn of LEFT face
- **L’** counter-clockwise 90° turn of LEFT face
- **D** clockwise 90° turn of DOWN face
- **D’** counter-clockwise 90° turn of DOWN face
- **U** clockwise 90° turn of UP face
- **U’** counter-clockwise 90° turn of UP face
- **B** clockwise 90° turn of BACK face
- **B’** counter-clockwise 90° turn of BACK face
- **F** clockwise 90° turn of FRONT face
- **F’** counter-clockwise 90° turn of FRONT face
Here is an example of how to track the movement of a tile. Using the Track the Rubik’s Cube sheet, color the Center tiles for the front, top, and right faces.

The RED Center will always be on the Front.

Made these turns: F R’ U’ R’ & U’ did not move the X.

Then made these turns: F’ L’

Then made this turn: B

Since you can’t see the X from the front view, you need to color the Center on the other views.