Instructor’s Manual
(GREEN PAPER)

60 copies, 2-sided, stapled
Please make sure stapling is correct and consistent
Meeting 8 Fall 2017

Fractal Dance
November 29th

Contents
1) Symmetries
2) Drawing fractals
3) Dancing Fractals

www.math.uci.edu/mathceo

2017 UCI MATH CEO COMMUNITY EDUCATIONAL OUTREACH. UNIVERSITY OF CALIFORNIA AT IRVINE
Fractal Dance (Meeting 8, Nov 29)

- Identify the mentor Leader
- Write names of any new mentors and students
  (find form inside folder, write new names if needed)
- Place checkmarks in the Meeting 8 column (same form inside folder)
- Share math goals with students in each activity
- Call students by their name
- Keep students silent while doing Quiz
- Keep your table neat and clean at all times
- Get help if there are behavior problems before they escalate

- Student Survey and assessment (pink) (start survey at 3:35 PM)
- Complete Meeting Report (blue) (if you are the Leader)
- Put back into folder: Student Surveys (pink), Meeting Report (blue)
Meeting 8: Fractal Dance

Dear mentor,

In Meeting 8 we will explore fractal symmetries by using our bodies. We will build to these “fractal dances” by thinking about symmetries more broadly, drawing fractals, and then “dancing” them.

Activity Breakdown

Activity 1 “Recognizing Symmetries” (15 minutes)
Students will discuss what symmetries are, what types of symmetries are there, and will practice identifying symmetries in images.

Activity 2 “Drawing Fractals” (15 minutes)
Students will draw a fractal square.

Activity 3 “Dancing Fractals” (45 minutes)
Students will come up with a fractal dance by dilating one parameter.

Math Goals

Be able to recognize and describe symmetries in different images.

Understand fractal symmetry across a range of forms.

Connect dilation and fractal symmetry to multiplication and ratios.
MATERIALS & AGENDA

MATERIALS

INSTRUCTOR MANUAL
Green color

STUDENT WORKBOOK
White color

MEETING REPORT
Blue Color
One per table

Online meeting report

STUDENT SURVEYS
(INCLUDES QUIZ)
Pink Color

WHITEBOARDS
One per student

DRY ERASE MARKERS
A pouch with several

AGENDA

- **2:05 pm** General Introduction  10’

- **2:15 pm** 1) Recognizing Fractals  15’

- **2:30 pm** 2) Drawing Fractals  15’

- **2:45 pm** 3) Dancing Fractals  50’

- **3:35 pm** Assessment  10’

- **3:45** End of the meeting

If you are missing any materials, please ask one of our assistants and they will be able to help you.

They can also help take your students to the restroom.
INDIVIDUAL ASSESSMENT

- In this meeting, both the math assessment and the student survey are done after the third activity, at 3:35 pm.

TIPS

- Build the habit of having students complete the quiz in complete silence and without any help of peers of mentors. This may take a few meetings, but make perfectly clear that we will work with these expectations. Do not ignore this.
- Correcting the Quiz after the students are done can help you check for understanding.

BEHAVIOR EXPECTATIONS

If a kid is behaving improperly or disrupting students, or does not follow directions at all, talk to them. If problem persists or is really serious, please let Brandi, Alessandra, Li-Sheng or an Assistant know immediately.

Refer to the expectations matrix and point to it if students are not meeting expectations.
**UCI MATH CEO MEETINGS: BASIC GUIDELINES FOR VOLUNTEERS**

1. **KNOW YOUR STUDENTS**
   - Call students by their names most of the time: make sure they know your name, talk briefly about their day before you start the math activities.

2. **ASK FOR EXPLANATIONS**
   - Ask students how they got their answers. Say things like “How do you know?”, “Why?”, “Draw a picture”, “Convince me!”, “Can you explain to Juan?” etc.

3. **MOVE & MONITOR**
   - Move around your table; monitor all students; use an adequate tone of voice; encourage kids to work in teams.

4. **CHECK WORK**
   - Verify that the students write the answers to the problems and that they are correct and complete.

5. **AT THE END**
   - Ask students to fill out the survey individually (no help), and to help pick up trash from the table and floor.

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**TEACHING TIPS**

This icon refers to specific tips which you will find embedded in the booklet activities: procedures, questions to ask to the students, recommended methodologies, and so on.

- **Can you explain the concept in your own words?**
  - Example: After you introduce a new concept, it is a good idea to ask students to rephrase the concept, explain it in their own words. You can choose particular students, for example those who are disengaged.

- **Can someone read the instructions out loud?**
  - Example: It is convenient to ask one student to read out instructions for a problem or definitions of a concept. This keeps your group focused on the task and improves their reading skills if you give feedback on reading.

- **Activity to be done in pairs**

  Note: if not specified, the booklet problem can be done as a group activity involving a discussion.
RECOGNIZING SYMMETRIES

Our Goal:
Identify different types of symmetry in images.

Discuss in your group. Everyone talks.

• What is the meaning of the word “invariant”?
• Make a list of the types of symmetry you know.
• For every type of symmetry you know, name an example of an object having that symmetry.
1) Which types of symmetry do you see in the image of...
The honeycomb?  The jellyfish?  The penguin?  The Romanesco cauliflower?

2) Are there any types of symmetry that you see that are not on your original list?
A **transformation** is an action changing geometrical shapes or objects. Here are 4 important types of transformations:

- **Translation**
- **Mirror reflection**
- **Rotation**
- **Do nothing**

A **symmetry** is a property that means that something in the figure repeats or is “invariant” (does not change) after a transformation.

- How many lines of reflections (mirror lines) does this snowflake have?
- What is the smallest angle of rotation that leaves the snowflake “invariant”?
A fractal is a geometrical figure that has “invariant elements” under repeated dilation. In other words, a fractal repeats itself repeats itself repeats itself repeats itself.

In addition to the first 4 types of transformations, consider one more, called dilation:

To *dilate* means to multiply the size (or some other quantity)
What types of symmetry does the cauliflower in the picture have?

• Does it have rotational symmetry? (If yes, what are the centers of rotation?)

• Does it have reflection symmetry? (If yes, what are the lines of reflection?)

• Does it have translation symmetry? (If yes, what are the axes of translation?)

• Does it have dilation symmetry? (If yes, what repeats at different sizes?)
Hints and Solutions…
Snowflake

- There are 6 mirror lines (lines of reflections).
  - Note that all such lines pass through the center of the central hexagon.

- The smallest degree of rotation is by a sixth of a full circle (60 degrees).
  - So by rotating the image 60 degrees, we obtain the same image. But this is not true if we rotate a smaller positive angle.
Cauliflower

• It has no rotational symmetry
(At the tip of each cone, there is a spiral with smaller cones distributed along the spiral... If you look carefully, the structure is not invariant under rotations.)

• It has dilation symmetry
(each of the smaller cones repeats the form of the larger cones).
Our Goals:
Create a fractal drawing as a group, relate the fractal symmetry to ratios and relate dilation to the multiplication operation.

Discuss in your group. Everyone talks.

With your group, think of step-by-step instructions for drawing this fractal.
Here are step-by-step instruction to construct this fractal:

- Step 0: Draw a big square: call it a “(0-)square”.
- Step 1: Draw a “(1-)square” at each corner of the 0-square.
- Step 2: Draw a (2-)square at each corner of a 1-square.
- Step 3: Draw a (3-)square at each corner of a 2-square.
- **Iterate** (that means, keep going in the same way...)

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<table>
<thead>
<tr>
<th>Step</th>
<th>Number of squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>4 x 3 = 12</td>
</tr>
<tr>
<td>3</td>
<td>4 x 3 x 3 = 36</td>
</tr>
</tbody>
</table>
```

Without counting, find how many (4-)squares will you draw in step 4.
What about in step 6?
A set of step-by-step instructions are provided in the previous page.

The kids may come up with alternative ways of building this fractal, and that is OK. Make sure you validate their answers.

At each step (from step 2 on), you draw a square at the 3 corners of each square that was drawn in the previous step.

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<td>(4 \times 3 \times 3 = 36)</td>
</tr>
<tr>
<td>4</td>
<td>(36 \times 3 = 108)</td>
</tr>
<tr>
<td>6</td>
<td>(108 \times 9 = 972)</td>
</tr>
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Materials

- 1 Piece of graph paper
- 3 colored markers per student

Introduction

In this activity, students will follow a simple algorithm (step by step procedure) to draw a fractal square. This is similar to what the artists did in the museum exhibit “Drawn from a Score” (Meeting 5).

Ask students to read page 3 in the Student Workbook and make sense of the instructions. Ask students to work in groups of 2. Each student will be responsible for one side of the drawing. Before executing each stage of the instructions, ask the students to explain what the instructions are saying, and make sure they are all in agreement about what the next stage of the drawing looks like. When they have completed the drawing, ask them to answer the question in the student workbook.
In groups of 2, students will draw a fractal square.

**First Step**
Each pair of students receives graph paper with a black square printed on it, and picks two (adjacent) sides to work on...

**Second step**
Each student draws all the outlines of the yellow square on its sides. The sides of the yellow squares are $\frac{1}{3}$ of the length of the sides of the black square. *(Students color each new square with yellow)*

**Third step**
Each student draws all the outlines of each of the red squares on their yellow squares. The sides of each red square are $\frac{1}{3}$ of the length of the sides of the yellow squares. *(Students color each new square with red)*
Once the drawing is complete, ask the following questions to students, in which you can reflect on the construction:

- How would you describe this shape to someone on the phone (that cannot see it)?
- How many squares did we draw in total?
- If we performed a 4th step, how many squares would we draw? (the algorithm is to draw a square in the middle third of each open face of the squares we drew in the last stage).
- What is the ratio of the area of the square drawn in a given step to the area of the square drawn in the step just before it?
Hints and Solutions...

At each step, you draw a square in the middle third of each open face of the squares you drew in the last stage. From step 2 on, squares have 3 open faces, so the number of squares drawn triples at each step.

Notice that, at each given step, the new square you draw has area = (1/9) of the area of the square you drew at the previous step.

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<table>
<thead>
<tr>
<th>Step</th>
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<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1/9</td>
</tr>
<tr>
<td>2</td>
<td>1/(9x9)</td>
</tr>
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<td>3</td>
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Our Goals:
Create a fractal dance as a group, by dilating along one parameter.

Discuss in your group. Everyone talks.

With your group, think of possible ways to bring symmetry into a dance
Transition to outside (downstairs classroom goes outside in the patio adjacent to class, upstairs classroom goes downstairs and assembles in front of NS2)

Warm-up (real quick):
“Everyone all together (in each small group) and do the symmetry dance:”
• Line up in pairs. Turn and face your partner, turn back to the front. (Reflection symmetry)
• Everyone spins in place (rotation symmetry).
• Step one step to the left (translation symmetry).

Ok, so symmetries can show up in dance too. Let us now focus on bringing the remaining symmetry (fractal symmetry) into a dance.
Create a fractal dance (15 minutes):
A fractal symmetry comes when we dilate (or multiply) a quantity such as size.

Question (for students):
*What quantities (things that we can measure) are involved in dance?*

Here are four quantities which we can dilate to obtain a fractal symmetry:
- Size of motion
- Duration of motion
- Number of bodies in the motion
- Force or intensity of a motion
Create a fractal dance (2/2):
Divide the students in groups of 3 or 4. Each group selects a parameter (size, duration, number of bodies or force/intensity). The task is to create a one minute dance, where dancers repeatedly dilate a quantity in a single motion.

- **Size** - e.g. tiny sidestep, small sidestep, big sidestep

- **Duration** – e.g. claps: clap 1 time & pause 1s; clap 2 times & pause 2s; clap 4 times & pause 4s

- **# of bodies** – e.g. one person says a word, two people say the word together, four people say the word together

- **Force/intensity** – e.g. one person goes slowly up from a crouch, one person stands from a crouch, one person bursts into the air from a crouch.
Dance your fractal (20 minutes):

Each group has 1 minute to share their dance with the rest of the class, **without telling** what quantity they dilated.

After each dance is performed, the members of the other groups have 1 minute to say what they observed, what fractal or other symmetries they saw, and try to guess the quantity that was dilated to generate the fractal symmetry.
PLEASE watch the very brief videos posted at the link below. We need every mentor to have a very good grasp of how to vary a parameter in a fractal dance.

Watching the videos will clarify the activity for you, and it will empower you to a better mentor and task leader for the kids at the meeting.

Thank you for your time!
Student’s Workbook
(WHITE PAPER)
15 pages + Cover

128 Copies, 2-sided, stapled
Meeting 8 Fall 2017
Fractal Dance
November 29th

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1) Symmetries
2) Draw a fractal
3) Fractal Dance
RECOGNIZING SYMMETRIES

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A **transformation** is an action changing geometrical shapes or objects. Here are 4 important types of transformations:

- **Translation**
- **Mirror reflection**
- **Rotation**
- **Do nothing** (Known as Identity)

A **symmetry** is a property that means that something in the figure repeats or is “invariant” (does not change) after a transformation.

- How many lines of reflections (mirror lines) does this snowflake have?
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DANCING FRACTALS

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Warm-up (real quick):
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  *(Reflection symmetry)*
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Dance your fractal (20 minutes):

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After each dance is performed, the members of the other groups have 1 minute to say what they observed, what fractal or other symmetries they saw, and try to guess the quantity that was dilated to generate the fractal symmetry.
Student Assessment & Survey
(Pink paper)
128 copies
2-sided
Please answer all questions individually

**PROBLEM 1**
Color (or shade) the drawing below so that it has no lines of reflection.

Now shade the drawing below so that it has 2 lines of reflections.

**PROBLEM 2**
Make a drawing with fractal symmetry.

What feature is dilated and repeated?

____________________________________________

____________________________________________
1) How boring were today's activities?
2) How satisfied are you with how you on today's tasks?
3) How did you feel while solving today's activities?
4) How much energy did you put into today's activities?
5) How close do you feel to your mentor at Math CEO?
6) How close do you feel to your peers at Math CEO?

Feedback for your mentor: ________________________

3 words to describe Math CEO: ________________________

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Clean your table when you finish, return the dry-erase markers, pick up your trash and take your belongings. Thank your mentor!
PROBLEM 1

(Take at the end of Activity 1)

Please answer all questions individually.

(A) Order the following 3 numbers from smallest to largest:

i) 27 x 8,  
ii) 28 x 7,  
iii) 26 x 5

Smallest: ________  
Middle: _________  
Largest: ________

Justify your choices.

(B) Complete the blanks with either values, "more" or "less". Examples are shown.

1) 45 x 23 is _______ more than 45 x 21.

2) 30 x 14 is _______ _________ than 31 x 13.
Meetings Report
(Blue paper)
Dear leader mentor,
Please complete this survey about each of the students at your table. Circle the number that better reflects how you feel. We really value your input. THANK YOU for your thoughtful answers, and for your amazing contribution to Math CEO.

<table>
<thead>
<tr>
<th>STUDENT'S FIRST NAME: ___________________</th>
<th>LAST NAME: ___________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compared to his/her peers, how good was this student at solving today’s math activities? 1 (worse) 2 3 (average) 4 5 (a lot better)</td>
<td></td>
</tr>
<tr>
<td>How much innate ability or talent in math did this student show today? 1 (not at all) 2 3 (a little) 4 5 (very much)</td>
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Any note or comment about this student? ________________________________________________________________________________
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