

## MATHEMATICS, BRAIN SCIENCE, AND PRACTICAL CLASSROOM APPLICATIONS TO FOSTER GROWTH MINDSET AND CONCEPTUAL UNDERSTANDING FOR ALL STUDENTS

Leslie Evans – Instructional Coach/Implementation Specialist  
Autumn Steinke – Program Specialist  
Utah Professional Development Network




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### OUTCOMES

- Participants will experience a rigorous math task in order to see how presenting a math task to students can enhance conceptual understanding, encourage multiple paths to sense-making, and demonstrate the benefits of a growth mindset.
- Participants will understand the shifts in brain and learning science due to discoveries in neuroplasticity, and will apply those ideas to classroom pedagogy.
- Participants will understand that well-designed math tasks encapsulate mathematical practices and that many are available from Stanford University's [www.YouCubed.org](http://www.YouCubed.org) site.

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### NUMBER TALK TASK

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### MATH TASKS & CONCEPTUAL UNDERSTANDING

- One key shift in the Utah Core Standards is increased rigor. The standards encourage teachers to give equal attention to conceptual understanding, procedural skills, fluency, and application.
- Well-crafted tasks help to guide students in their application of the Mathematical Practice Standards.

*Task resources:*

- <https://www.youcubed.org/tasks/>
- <https://www.illustrativemathematics.org/progressions>

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UTAH CORE  
STANDARDS



## Math Practice Standards

1. **Make sense of problems and persevere in solving them.**
2. **Reason abstractly and quantitatively.**
3. **Construct viable arguments and critique the reasoning of others.**
4. **Model with mathematics.**
5. **Use appropriate tools strategically.**
6. **Attend to precision.**
7. **Look for and make use of structure.**
8. **Look for and express regularity in repeated reasoning.**

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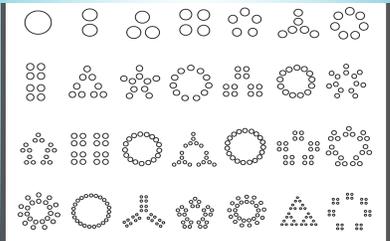
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DISCUSSION – TURN AND TALK  
HOW MIGHT THIS TASK ENCOURAGE CONCEPTUAL UNDERSTANDING AND USE OF MATH PRACTICE STANDARDS?

Task Directions



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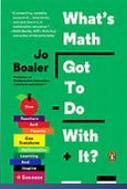
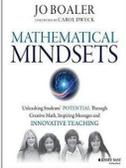
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youcubed at Stanford University

Brain Science · Week of Math · Ideas & Tasks · Courses · Parents · Students · Resources · Community · Q



Dr. Jo Boaler


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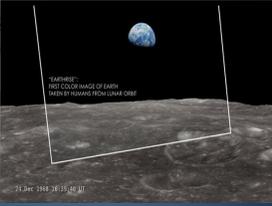
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"That must have been the paradigm shift."

PARADIGM: FIRST COLOR IMAGE OF EARTH TAKEN BY HOWARD FROM LUNAR ORBIT

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A paradigm shift, as identified by American physicist Thomas Kuhn, is a fundamental change in the basic concepts and experimental practices of a scientific discipline.

...Education? Special Education??

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**Fixed**      **Growth**





**HISTORICAL UNDERSTANDING**

- You're born with a certain amount of intelligence and it isn't something that can be changed
- Talent is something you're born with, not something you can develop

**NEW UNDERSTANDING**

- Intelligence can increase or decrease depending on how you spend time exercising your mind
- Learning new things can increase your underlying intelligence

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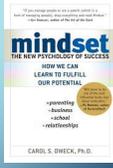
**MINDSET MATTERS...**



Dr. Carol Dweck

**Fixed mindset**  
Intelligence is a fixed trait. You can't change it.

**Growth mindset**  
You can grow your intelligence through effort.



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Growth Mindset	Fixed Mindset
<p>Intelligence can be developed leads to a desire to learn and therefore a tendency to</p> <p style="text-align: center;">↑</p> <p style="text-align: center;">challenges</p> <p>embrace challenges</p> <p>persist in the face of setbacks</p> <p>see effort as the path to mastery</p> <p>learn from criticism</p> <p>find lessons and inspiration in the success of others</p> <p>they reach ever-higher levels of achievement</p>	<p>Intelligence is static leads to a desire to look smart and therefore a tendency to</p> <p style="text-align: center;">↓</p> <p style="text-align: center;">avoid challenges</p> <p>avoid challenges</p> <p>give up easily</p> <p>see effort as fruitless or worse</p> <p>ignore useful negative feedback</p> <p>feel threatened by success of others</p> <p>they may plateau early and achieve less than their full potential</p>
<b>RESULTS</b>	<b>RESULTS</b>

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## GROWTH MINDSET AND ACHIEVEMENT

- Decades of research show a powerful relationship between **mindset and achievement.**

- Students' **beliefs** about intelligence and learning impact:
  - Motivation
  - Academic behaviors (e.g., studying and seeking help)
  - Responses to challenges and setbacks
  - Academic achievement




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## THE BRAIN AND MISTAKES

- Every time a student makes a mistake, a synapse fires.
- The synapse appears to fire when the student is struggling, even if they are unaware they are making a mistake.
- When that student becomes aware they made a mistake, a second synapse fires.
- Mistakes are not only beneficial for learning, but they make a brain grow.
- **Brain growth is greater for those with a growth mindset.**

Massey, J.S., Schroder, H.S., Heitler, C., Moran, T.P., Lee, T.-H., 2011. Mind your errors: evidence for a neural mechanism linking growth mindset to adaptive post-error adjustments. *Psychological Science* 22, 1484 – 1489.

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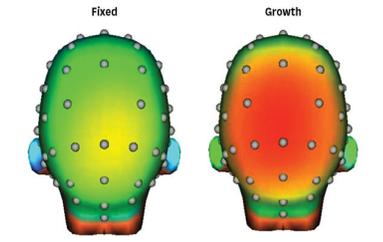
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These two brain images from the study, are voltage maps showing the activity in the brains of those with a growth and fixed mindset. The orange color of the growth mindset brains reflects the greater activity in the brain with more intensity and attention to error.



(Mangels, Butterfield, Lamb, Good, & Dweck, 2006)

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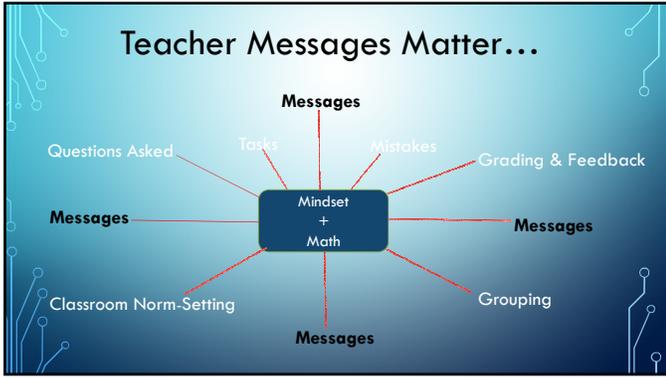
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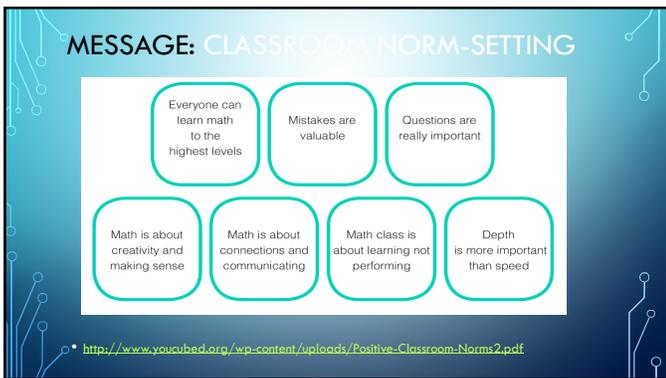
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ESTABLISHING CLASSROOM NORMS

 Brain Science > Week of iMath > Ideas & Tasks > Courses > Parents > Students > Resources > Community > Q

<https://www.youcubed.org/>

- Week of iMath
  - Week of Inspirational Math 1
  - Week of Inspirational Math 2
- register for free!

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A VIDEO FROM WEEK OF INSPIRATIONAL MATH  
WEEK 2, DAY 1 – “MISTAKES ARE POWERFUL”



<https://youtu.be/Ukt4A5GcfOU>

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MESSAGE: TASKS

Growth Mindset Task Framework

1. Openness
2. Different ways of seeing
3. Multiple entry points
4. Multiple Pathways/ Strategies
5. Clear Learning Goals and Opportunities for Feedback

<https://www.youcubed.org/tasks/>

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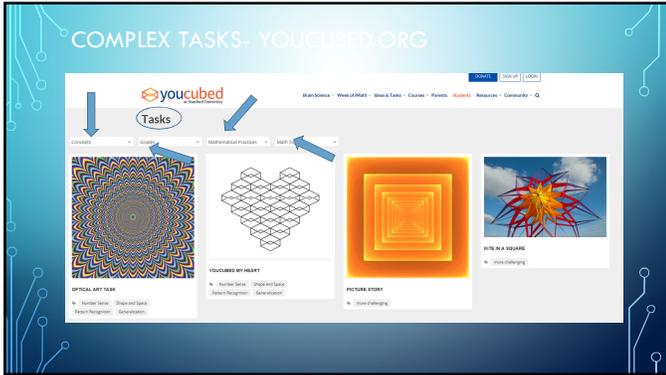
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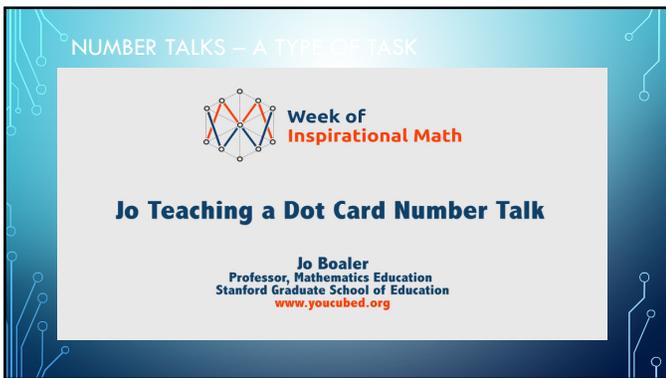
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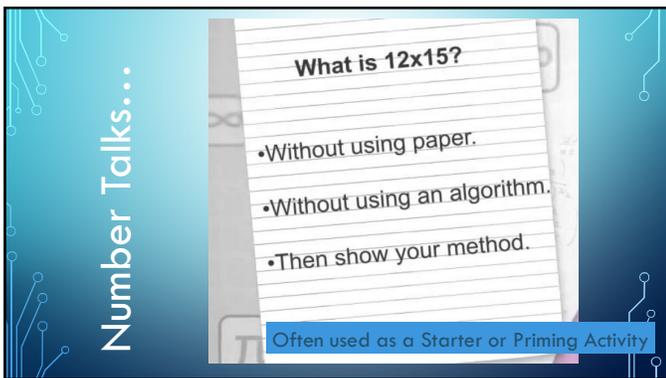
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**MESSAGE:**  
QUESTIONS ASKED

During tasks

Number talks

In response to student mistakes

**Powerful Questions to develop a deep level of understanding**

How do you see that idea?

Why does that answer make sense?

Why does that method work?

How is that method connected to others?

How can that idea be represented in different ways?

Can you prove it?

Can you prove it visually?

Can you justify your thinking?

Can you predict what would happen if....?

Did you make any interesting mistakes?

Developed by Jo Boaler/Youcubed.org and Tulare County Office of Education

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**MESSAGE: GROUPING**

1. The messages they give
2. Teacher expectations
3. The work they are given
4. Middle group teaching




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**TURN AND TALK**

**Fixed or Growth?**

What messages are sent when we group students:

- Homogeneously?
- Heterogeneously?
- Pullout?

Grouping isn't inherently bad. We must be thoughtful.

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## WEEK OF INSPIRATIONAL MATH

### WEEK 1, LESSON 1 GROWER NORMS

<b>Day 1</b> Inspiring Ideas: "Wanted: Evergreen" <a href="#">Materials</a>	We start this lesson with an activity that helps students learn to work well in a group. This will help students when they engage in group work for the year ahead. We then introduce a powerful inquiry task called Four 4's. This invites students to math they take at home and continue with their parents and friends! It is a great task for seeking important number facts and relationships while engaging students in open inquiry. We have chosen it for the first day as it also helps students to feel comfortable sharing their thinking.	<b>Content:</b> All number operations <b>Practices:</b> MP1: Make sense of problems and persevere in solving them <b>MP6:</b> Attend to Precision
<b>Day 2</b> Visualizing Numbers: Make of Data! <a href="#">Materials</a>	In this lesson we share a really cool and different way of looking at numbers, which will help students see factors and multiples. Students are invited to look for patterns and to color, label and ask their own questions about the resulting representations. This lesson created "buds" and "wax" throughout the year in our class - students were fascinated by the numerical relationships they saw, often for the first time.  In the extension activities investigating consecutive numbers students can receive opportunities to understand the meaning of algebraic expressions.	<b>Content:</b> Factors, multiples, prime numbers, number relationships, algebraic expressions and equations <b>Practices:</b> MP1: Look for and make use of structure <b>MP6:</b> Look for and express regularity in repeated reasoning
<b>Day 3</b> Popping Geometry with Brain Flip-Flop! <a href="#">Materials</a>	In this lesson we invite students to engage in a different type of mathematical thinking through a paper folding task. The task is interesting and challenging but students know everything they need to solve it. The students are also taught to be skeptical and to conjecture and reason. A 10 minute activity on visualizing is integrated into this lesson; you can watch a video of go teaching the visualizing activity <a href="#">here</a> .	<b>Content:</b> Area, fractions, triangles, squares, estimation <b>Practices:</b> MP1: Make sense of problems and persevere in solving them <b>MP3:</b> Construct viable arguments and critique the reasoning of others <b>MP4:</b> Model with mathematics

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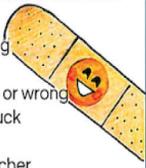
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## MESSAGE: MISTAKES MAKE YOUR BRAIN GROW!

**The classroom is a risk-taking, *MISTAKE VALUING* environment**

- Students share ideas even when they are wrong
- Peers seek to understand rather than correct
- Students feel comfortable when they are stuck or wrong
- Teachers and students work together when stuck
- Tasks are low floor/high ceiling
- Students disagree with each other and the teacher



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## A QUICK GUIDE

### 1. A MISTAKE IS FOUND

**Teacher says:** "Oh, would you go and present that on the board?"

**Student response:** "But I got it wrong,"

**Teacher explains,** "You know, it's really great for us to see mistakes because the ones students made, others will have, and we will all learn."

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### 2. SPEND TIME REFLECTING ON DISCUSSING THE MISTAKE

- Teacher asks student to reflect on what happened and why:
- Choose one or more of the following:
  - a) What happened when you made the mistake (when you were explaining your strategy)?
  - b) How did you realize you had the wrong answer?
  - c) Tell us about how you started the problem? Why was that in your brain?
  - d) How did it feel when you realized you had the wrong answer?
  - e) What did you learn from it?

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### 3. ACKNOWLEDGE STUDENT LEARNING AND GROWTH

- Teacher thanks student for sharing and asks rest of class what learning was gained in the mistake.
  - Teacher explicitly references the growth either by referring to class poster, praising the student for growing and allowing others to share if they made a similar or different mistake.
- Example teacher responses:
- "By the way, I just want you to know that I love mistakes the most. They're the time when your brain grows, when you really learn. So it's really great to make mistakes."
  - "I love that so and so helped us learn something new today."
  - "Who else made the same mistake or a different one?"

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### STUDENT MISTAKES MOMENT

• <https://www.youtube.com/watch?v=M-gYFUnlDdg>

• .25- 5:00



• <https://www.mindsetkit.org/topics/celebrate-mistakes/give-work-encourages-mistakes-see-action>

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## BUILDING A MATHEMATICAL MINDSET COMMUNITY

**Teach and observe before you tell**  
 • Do not tell students what to do or think.  
 • Do not tell students what to do or think.  
 • Do not tell students what to do or think.

**The growth mindset**  
 • Growth mindset is the belief that abilities can be developed through dedication and hard work.  
 • Intelligence, talent, ability, and creativity are skills that can be developed through hard work.

**The environment is filled with related and relevant math**  
 • Math is everywhere.  
 • Math is in the world around us.  
 • Math is in the things we do every day.

**Recommendations for Task/Lesson Design**  
 • Expect the task to encourage multiple methods, approaches, and opportunities.  
 • Have a purpose before teaching the method.  
 • Design a task that allows all learners to contribute to the learning and have room for elaboration.  
 • Make opportunities for students to authentically share their thinking with peers.  
 • Add a visual component.  
 • Add the opportunity to practice and receive, but not demand.

**Provocative Questions to Develop a Deep Level of Understanding**  
 • How do you see that about?  
 • Why does that answer make sense?  
 • How is that method connected to others?  
 • How are other similar representations or problems different?  
 • Can you prove it?  
 • Can you prove it is incorrect?  
 • Can you prove what would happen if...?  
 • Did you notice any interesting mistakes?

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## ESTABLISH GROWTH MINDSET (OTHER SUBJECTS)

- [https://storage.googleapis.com/mindsetkit-upload/05e7\\_kiCekZJc/L2FwcGhvc3RpbmdfcHJvZC9ibG9icy98Bw3L-MIVx12F1TlMuTPNLR1VJZXlmbm9TNEltWY5NmRUN3duYkI3RTlhQm1LQVYlraGh1Smqaqllwb2Q1vzRSktoRHZUImVnom1ldGYxN2dnTVAdMjQwUUhXYWVlaTRUQ55ZbHJMaVhMAM2u0T19NRUZp](https://storage.googleapis.com/mindsetkit-upload/05e7_kiCekZJc/L2FwcGhvc3RpbmdfcHJvZC9ibG9icy98Bw3L-MIVx12F1TlMuTPNLR1VJZXlmbm9TNEltWY5NmRUN3duYkI3RTlhQm1LQVYlraGh1Smqaqllwb2Q1vzRSktoRHZUImVnom1ldGYxN2dnTVAdMjQwUUhXYWVlaTRUQ55ZbHJMaVhMAM2u0T19NRUZp)
- [https://www.youtube.com/watch?v=KUWn\\_TJTrnU](https://www.youtube.com/watch?v=KUWn_TJTrnU)

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## QUESTIONS?

Thank you

- [Leslie.evans@osu.edu](mailto:Leslie.evans@osu.edu)
- [Autumn.Stehlik@osu.edu](mailto:Autumn.Stehlik@osu.edu)

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