Why Are These Students Two Years Behind?
Preliminary Research Summary

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Over the past 2 years, I've filmed 100 6th grade students at a high-poverty school as they tackle tasks involving fractions, looking for evidence of learning styles while coaching the school's math department on effective teaching strategies. The mathematics professional learning community (PLC) chose to focus on fractions instruction because of its foundational importance to algebra. We used the information from the filming project to inform instruction in the school's heterogeneous math classrooms and to plan interventions. Most of the students I selected for filming were about two years below grade level in proficiency, according to standardized tests. The filming project and the intervention work convinced the teachers of the importance of addressing learning style needs when students fail to grasp mathematics concepts during regular instruction.

The Learning Styles

This school uses the theory of Jungian type to frame learning styles and differentiation. Jung postulated that people have natural preferences for how we are energized, gather information, make decisions, and approach work and life, all of which affect how one teaches and learns. Handout 1 contains a further explanation of these preferences:

> *Extraversion and Introversion:* This natural preference defines how people are energized. Extraverted types are energized through action and interaction. Introverted types are energized by time for reflection.

Sensing and Intuition: This natural preference defines how people gather information. Sensing types attend first to reality, what their five senses and prior experiences can tell them. Intuitive types attend first to the unseen world of hunches, connections and analogies.

All normal people can use all four of these preferences, just like we can hold a pencil and scribble something with both hands. However, we *prefer* one preference over the other in each pair, just as most of us write with a preferred hand.

These four preferences combine to form four different learning styles, as described in Handout 2, which address diverse student needs for energy and information, two key factors in any classroom experience. To succeed at school, students need to develop skills with all the preferences; it isn't helpful to always learn in one's own style, but confidence in one's abilities often results from learning new concepts in one's own style. Here is a quick summary of what we saw in this project:

- The differences in the four learning styles are visible, even to those with little formal type training
- Students who are proficient in mathematics can learn in any style
- Students have biases about which styles are "smart" that sometimes block them from effective learning strategies
- Teachers may misinterpret the work of students whose learning style is different from their own
- Students who are multiple years behind benefit greatly from interventions conducted in their own learning styles.

The Filmed Tasks

The fractions tasks chosen were designed to show student thinking as they worked. The tasks were:

1. Make a shape that is 1/4 red and 3/4 yellow. Then make one with more squares or tiles that is still 1/4 red and 3/4 yellow.
2. Make a shape that is 1/6 red, 1/6 green, 1/3 blue, and 1/3 yellow. Then make one with more squares or tiles that still has the same fractional parts.
3. A rectangle is 1/2 red, 1/3 blue, and has 1 green tile and 1 yellow tile. What might the rectangle look like? Draw or build it.[1]

Students were free to choose from a variety of supplies: markers, colored pencils, color tiles (one-inch squares of wood painted red, yellow, blue or green), blank paper, one-inch gridline paper, and isometric graphing paper ideal for drawing triangles, hexagons, and other shapes which have angles other than 90 degrees.

While the two students with high standardized test scores (filmed for control purposes) completed the three tasks in less than ten minutes, some students were not able to complete the first two in 40 minutes, even with individualized instruction. There were striking differences in how students approached the tasks, shown in Handout 3; misunderstandings were similar but how they tackled the problem and the resulting solutions clearly tied back to their learning styles. Students from different cultural backgrounds (African American, Hmong, white European, and East African) were present in each of the learning styles.

The immediate application of the filming, though, was to help the teachers understand what might block student understanding and to plan for interventions. The entire team

[1] Adapted from Burns, M. (2000). *About teaching mathematics: A K-8 resource, 2nd ed.* Sausalito, CAL Math Solutions Publications, p. 235.

watched a film of one student, Rashan[2], who preferred Extraversion and Sensing and revealed on an attitude survey that he was afraid he just couldn't do math.

When the filming facilitator informed Rashan that he'd be completing fractions tasks, he murmured, "Oh, dear. I'm not good at any of it. Especially dividing," and buried his face in his hands. Given that division of fractions had not yet been covered—in fact the class was still working on addition of fractions with like denominators—his lack of self-confidence was especially striking. Below are two excerpts from the film transcript:

Facilitator (F): Record a geometric shape that is 1/4 red and 3/4 yellow.
Rashan (R): Geometric means that [slicing motion vertically with hand] anything that goes down along like that?
F: Any shape. You can do a square, a rectangle, a triangle. Whatever shape you want to draw. Just make sure that when you color it in or you build it that it's 1/4 red and 3/4 yellow.
R: Okay. [Draws a 2"x4" rectangle on blank paper. Whispers to self, "Oh boy, let's see, about…" Grabs red pencil and hesitates.] Does it have to be 2 different shapes?
F: Nope, all in the same shape.
R: Okay… [Draws red square in 1 corner of rectangle equal to approximately 1/8 of the shape, colors it, looks back at problem card] Oooooh, okay, now I'm starting to get it. [Turns paper over] Now I get it. [Draws new rectangle quickly with blue pencil, uses red pencil and draws 2 vertical lines that create thirds, hesitates before coloring] I need a different sheet of paper [reaches for clean one and completes task correctly]
F: Okay, so tell me how you thought about that.
R: So then you have 3 plus 1 is 4 and at each one of the numbers you have a 4 and it's telling you that you have just 1 square and it's gonna have 4 squares in it and they're supposed to be those two colors in both of them.

Watching the film, his teachers quickly discerned how Rashan used concrete representations and trial and error to make sense of the problem. Note below how his understanding of the meaning of "4" affects his ability to complete the second task.

F: Record a geometric shape that is 1/6 red, 1/6 green, 1/3 blue, 1/3 yellow.
R: Okay…[gets all the right pencils] okay, let me see…[quickly draws 3x5 rectangle on blank paper, divides it in 6ths] 1/6 red [colors 1 square red] 1/6

[2] All names have been changed.

green [colors 1 square green, 1 square blue, hesitates, colors 1 square yellow. Looks back at problem and taps pencil.] Oh my goodness.

F: Tell me what's going on in your head.

R: [grabs and shakes head] I actually thought it would be 6 squares and this one red and these two, and then there should be 3 blocks left over.

F: Why did you think there should be 3 blocks left over?

R: Because there's 3's at the end of them and I think that when it says 1/3 you should color one of these two colors out of the three that was left over. But obviously not.

F: So you thought that if you colored this one out of six and this one out of six, then there would be three left because of the 3 in these 1/3's.

R: Yeah, and then, but obviously not 'cause I thought you were supposed to have 6 squares for the sixths 'cause you'll have to color in one out of the six squares. And, that didn't happen.

Rashan's methods and struggles were similar to other students we filmed who preferred Extraversion and Sensing[3], summarized in Handout 2.

The teachers also viewed part of a film of a student with the opposite learning style, Introversion and Intuition, who ignored the tiles and paper and built her first shape of one red and three yellow markers. One of her teachers commented how this reflected her constant drive for individuality, remarking, "I thought her inability to finish worksheets was due to laziness or apathy, but they bore her to tears, don't they?" The contrasting films of these two students with identical test scores focused the ensuing discussion on the need to differentiate instruction for learning styles as well as ability.

The Interventions

While mathematics instruction took place in heterogeneous classrooms, the teachers decided to form small groups by learning styles for the interventions. Handout 4 provides a few examples of the differences in how students with different learning styles approached some of the intervention activities. One teacher worked with a group that preferred

[3] Student learning styles were assessed through the MMTIC®, published by CAPT (www.capt.org), and student confirmation through self-discovery activities (Kise, 2007).

Introversion and Sensing and another group that preferred Extraversion and Intuition. His experiences illustrate the effectiveness of the groupings.

> One of the first concepts I tackled was the relationship between mixed numbers and improper fractions. I used a variety of activities—fraction strips, drawing models, working on individual whiteboards, and so on. Even though the two groups started from approximately the same knowledge base, the Extraverted and Intuitive group seemed to master the concepts in just a couple of days and were ready to move on.
>
> In contrast, it took the Introverted and Sensing group four days to master the concepts. However, when the light bulb went on, it was the highlight of my teaching career. The students eagerly wrote new problems for each other to try, demonstrated to the principal what they had learned, and asked if they could do more of the problems the next day. I have the feeling that since first grade, those students have viewed math as magic, something they would never understand. This may have been their first experience in mastery. I've seen an immediate change in their attitude in my regular classrooms, as if they now know they can make sense of it.
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> Four days may seem ridiculous, but what if they'd been given that time to catch on in first and second grade? Where would they be now?

This is not to say that all Introverted and Sensing students need this much time to grasp concepts, but that these students flourish when they are allowed to cement concepts before moving on. In contrast, the Extraverted and Intuitive students flourish with a more rapid pace and a wider variety of activities.

Conclusion

An interesting side note on showing the fractions films to teachers is their reaction to the amount of time it takes students to complete the tasks. Glance back at the transcript excerpt from Rashan's work on the first problem. One teacher commented in a workshop, "I would have intervened after his first mistake, not wanting him to fail. That would not have helped, would it? The student needed time to make meaning." Since then, I've asked every group to which I've shown the film how many of them would intervene. About 80 percent say that they probably would have.

Invariably, one of the participants will interject, “But we don’t have time for students to make multiple attempts like this boy.” And, someone else will say, “So we don’t have time in schools for students to learn?”

Merely grouping by learning styles, or designing activities by learning styles, isn’t enough. Instead, we need to be acutely aware of what each group needs, help them learn to advocate for their needs, and make room for those needs, especially when school is leaving them behind.

Rashan was part of one of our small intervention groups. By the second hour of the intervention, he was up at the document camera, defending his placement of 5/4 on a number line. Later, when he completed a fractions addition problem, he asked, “Can I take this paper home to show my dad? He isn’t going to believe I did this.” Deep, rigorous knowledge and use of learning styles can result in students believing that they can do the math.

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Handout 1

Extraversion or Introversion:

Where do you get your **Energy?**

Extraversion (**E**) Gaining energy through action and interaction, the outside world
Introversion (**I**) Gaining energy through reflection and solitude, the inner world

EXTRAVERSION	**INTROVERSION**
☐ Thinks out loud (talks!)	☐ Thinks inside (quiet!)
☐ Likes to work in groups	☐ Likes to work alone or with close friend
☐ Likes noise	☐ Dislikes noise
☐ Prefers to speak	☐ Prefers to read or write
☐ Lots going on	☐ One activity at a time
☐ Says what they're thinking	☐ Keeps thoughts inside

Circle which describes you best:

E (Extraversion) **I** (Introversion) **U** (Not Sure)

Sensing or Intuition:

What **Information** gets your attention?

Sensing **(S)** *First* paying attention to *what is,* to information you can gather through your five senses—the facts.
INtuition **(N)** *First* paying attention to what *could be,* to hunches, connections or imagination—a sixth sense.

SENSING	**INTUITION**
☐ Likes facts and concrete things	☐ Likes ideas & imagination
☐ Experience first	☐ Explanation first
☐ Sees the trees—details	☐ Sees the forest—big ideas
☐ Wants clear expectations	☐ Wants room to roam
☐ Step-by-step learning	☐ Random learning
☐ Practical, common sense	☐ New insights

Circle which describes you best:

S (Sensing) **N** (INtuition) **U** (Not Sure)

Note: There are two other preference pairs: Thinking and Feeling (two approaches to decision-making) and Judging and Perceiving (two approaches to our desire for openness or closure in work and life in general). These also play a role in mathematics instruction but were not as significant in the film project research and could not be covered in the short presentation framework of this conference.

Handout 2

Learning Styles

While all eight psychological preferences are important for teaching and learning, concentrating on Extraversion, Introversion, Sensing and Intuition ensures that students have the **energy** and the **information** they need to learn.

If teachers begin by planning in their normal style, or through the curriculum, and then adjust for the quadrant whose needs are least met, they will in fact meet the needs of all four quadrants. This creates a manageable process for differentiation. As teacher type knowledge increases, they can make further adjustments.

IS: Let me know what to do	**IN: Let me follow my own lead**
• Set clear expectations and goals • Show me examples • Provide the steps in the process • Answer my questions as I have them • Give me time to think • Let me work with and memorize facts • Avoid too many surprises • Build on what I know • Let me know along the way if I'm doing things right • Connect content with past efforts and experiences	• Let me delve deep into things that interest me • Avoid repetition and routine • Let me figure out for myself how to do things • Give me choices • Listen to my ideas • Let me learn independently • Let me start with my imagination • Help me bring what I envision into reality • Give free rein to my creativity and curiosity • Provide references for me to build my own knowledge base
ES: Let me do something	**EN: Let me lead as I learn**
• Start with hands-on activities • Give me steps I can follow • Let me think out loud and work with others • Tell me why I'm learning something • Give me chances to talk and move • Set a realistic deadline • Give me examples • Provide clear expectations • Go light on theory • Let me use my experience and skills	• Start with the big picture, not the details • Let me dream big without penalties • Let me find a new way to do it • Let me interact with others • Give me choices • Keep changing what we do • Let me teach or tell someone what I've learned • Le me be in charge of something • Let me talk or work in groups • Let me come up with my own ideas

Handout 3

Learning Style Characteristics Seen In Math Task Films

For this project, 35 6th grade students were filmed while completing fractions tasks. All had access to markers, plain paper, 1" square paper, isometric graph paper, and color tiles. The following information summarizes the differences in ways students with different learning styles approached the same tasks.

Introversion and Sensing (IS)

At their best:

- Asked questions to clarify understanding
- Checked work before explaining answer
- Applied a literal interpretation of some of the problems, leading to quick solutions

Struggles

- May not be willing to experiment if they are uncertain
- Were easily confused by examples if they aren't chosen carefully
- Hesitated to ask questions, thinking they should know

Task behaviors

- Used squares paper and markers; none used tiles unless the facilitator suggested it
- Only one used numbers to find common denominators

Introversion and Intuition (IN)

At their best:

- Showed perseverance when exploring their thinking
- Looked for innovative ways to solve a problem
- Applied learning from one problem to next

Struggles

- Made careless mistakes that interfered with their thinking
- Trusted own hunches too much, not seeking clarification or new information

Task behaviors

- Frequently drew shapes other than rectangles or used isometric graph paper
- One student built shapes with markers rather than the tiles
- Worked quietly for up to nine minutes on a task
- Most used numbers to find common denominators

Extraversion and Sensing (ES)

At their best:

- Experimented with tiles and drawings to find solutions
- Quickly asked for clarifications
- Clearly articulated ideas and questions

Struggles:

- Asked for feedback continually
- Inaccuracies in drawings affected their thinking
- Struggled to transfer concepts to new problems. For example, if they understood how to make a bigger shape including fourths, that knowledge did not transfer to the problem concerning sixths

Task behaviors:

- Altered the materials to make sense of problems (only ones who shaded tiles, divided graph squares in half, etc., to fit in thirds and sixths)
- Used trial and error without asking for help in between experiments
- None used numbers to look for common denominators

Extraversion and Intuition (EN)

At their best:

- Applied knowledge from one problem to the next
- Confidently proceeded on their own understandings

Struggles

- Accuracy in counting and in explanations
- Struggled to unlearn something that they inferred or a conclusion they drew
- Communicated in general terms that increase difficulty of clarifying their misunderstandings

Task behaviors

- Careless mistakes; used colors that didn't match problem or counted tiles and squares incorrectly
- Unaware of the denominator they were illustrating, i.e., talking about 12ths while illustrating 10ths.
- So confident in their answer that they didn't see mistakes even while explaining their solution
- Long verbal explanations

Handout 4

Implications for Mathematics Instruction

The following chart illustrates the different ways students of each learning style engaged in the same activities during fractions help sessions.

Activity 1: Students built shapes with specific fractional parts, using color tiles. Each student worked behind an upright binder so they couldn't see each other's work. Each had a red/green card that they placed on top of the binder and turned to "red side" when they were ready for an instructor to check their work or when they had a question. Goal: Understanding the meaning of the numerator and denominator.

Activity 2: Students, working in pairs, rolled fractions dice, recorded the fractions on individual whiteboards, modeled the equation with fraction strips, and then added the fractions. Goal: finding equivalent fractions and adding fractions.

Introversion and Sensing • Activity 1: These students often asked for extra practice. For example, the activity directions asked them to build a 3-tile shape that was 1/3 blue, then a 4-tile shape that was 1/4 blue. Many wanted more simple tasks such as this (1/5 blue and so on) before moving on to more complex tasks. • Activity 2: Although they were only asked to complete and record 5 different dice rolls, many of these students completed 10 or more. They worked side by side but often independently. One group turned their dice to ensure they got to do the hardest problem, 1/12 + 1/16, before stopping. They kept using the fractions strips until the instructor asked them whether they could do the problems without them.	**Introversion and Intuition** • Activity 1: These students quickly mastered the concept of building shapes with different fractions. Several asked to draw rather than build shapes, and also quickly moved to working independently on tasks such as the second and third ones in the filming project. • Activity 2: These students rushed through the task, frequently getting most of the 5 required problems wrong. In some cases we stood by their side until they showed us how to model the equation with the fraction strips. This seemed to solidify the concept. We then required 5 *correct* equations before they could move on and this seemed to motivate them to be more careful. They engaged more deeply when asked to use model drawing to solve word problems involving adding fractions.
Extraversion and Sensing • Activity 1: These students frequently told us how much they liked working with the tiles, saying, "I can *see* the fractions." They contentedly built towers and other shapes with the tiles while waiting for the instructor to check their work or to answer a question. Several spontaneously tutored their classmates after they'd mastered the concepts. • Activity 2: These students loved the chance to sit on the floor to roll the dice, coming up with their own rules for the toss. They also enjoyed working together with the large magnetized strips on the classroom whiteboards to grasp the concept of equivalent fractions.	**Extraversion and Intuition** • Activity 1: These students quickly mastered the concept of building shapes with different fractions and enjoyed working together to solve some of the harder problems such as the second and third ones in the filming project. They frequently miscounted their tiles or used the wrong colors. • Activity 2: These students enjoyed rolling the dice, but like the Introverted Intuitives made mistakes at first because they hadn't solidified the concepts through use of the fractions strips. Once they were required to solve a few problems with the fractions strips, they were able to complete new problems correctly.