THE DEVELOPMENT AND EVALUATION OF A FAMILY-CENTERED PICTURE BOOK INTERVENTION FOR EARLY MATH LANGUAGE

David J. Purpura, Ph.D.
Human Development and Family Studies
Purdue University
Erikson Institute, Promising Math Conference
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purpura@purdue.edu / @davidjpurpura
THANKS TO MY COLLABORATORS!!!
Kelly
Basic cognitive processes linking symbols, words, and quantities

Omo/Kieth
High-quality parent child interactions by supporting the environment
LINKING THE TALKS

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Omo/Kieth
High-quality parent-child interactions by supporting the environment

Me
Using our knowledge of basic processes and family interactions to build and evaluate interventions that support math development through high-quality parent-child interactions
OVERVIEW

- Background on home engagement and math Language

- Part 1 – Intervention Development and Refinement Process
  - Book Development
  - Book Refinement
  - Piloting

- Part 2 - Randomized control trial of the intervention

- Next Steps
Parent-child home engagement in educational activities is important for children’s academic development

- One of the most common home engagement activities is reading...

- Reading general books occurs a few times a week to nearly every day
- Reading math/number books occurs a few times a month to once a week

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- Reading math/number books occurs a few times a month to once a week.

Why?
LIMITATIONS OF EXISTING BOOKS

- Few math-focused books focus aspects other than numbers 1 to 10 (Powell & Nurnberger-Haag, 2015)
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- Illustrations in some books may make engaging in math activities more challenging (Ward, Mazzocco, Bock, & Prokes, 2017)
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- Most books focused on math are not engaging (My Kids, 2012, 2014, 2016a, 2016b)
  - No storyline, no consistent characters, little engagement for repeated reading
LIMITATIONS OF EXISTING BOOKS

5 bananas
five

Started bagel

Finished bagel
Picture book reading can be a potential context for engaging children in math

- Preschool teachers (Piasta et al., 2014) and parents of preschool children (Thompson, Napoli, & Purpura, 2017) engage in very limited math activities with their children.

- Reading picture books occurs frequently in school and at home and has been demonstrated to be a tool for improving mathematics (Anderson et al., 2005; Casey et al., 2004; Hojnoski et al., 2014; Jennings et al., 1992; Young-Loveridge, 2004)
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- Reading picture books occurs frequently in school and at home and has been demonstrated to be a tool for improving mathematics (Anderson et al., 2005; Casey et al., 2004; Hojnoski et al., 2014; Jennings et al., 1992; Young-Loveridge, 2004)

- One particular aspect of mathematics that may be supported through picture book reading is mathematical language (Purpura, Napoli, Wehrspann, & Gold, 2017)
MATHEMATICAL LANGUAGE

- Early math involves specific math language (Purpura & Reid 2016)

- Need to know quantitative and spatial mathematical terms
  - Quantitative: more, less, fewer, a lot, some
  - Spatial: before, after, near

- Math Language = key terms and concepts (e.g., more/most)

- Numeracy skills = counting, numeral identification, addition/subtraction
SIMILAR NOT SAME
Math language is:

- More proximal to math performance than is general language (Hornburg, Schmitt, & Purpura, 2018; Purpura & Reid, 2016; Toll & van Luit, 2014a)
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- A better risk classifier of later math difficulties than is initial math performance (Purpura, Day, Napoli, & Wehrspann, 2017)
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- A better risk classifier of later math difficulties than is initial math performance (Purpura, Day, Napoli, & Wehrspann, 2017)

- Improving math language also results in improved numeracy skills (Purpura, Napoli, Wehrspann, & Gold, 2017)
DEVELOPING A FAMILY-CENTERED MATH PICTURE BOOK INTERVENTION

- ...designed to improve math language and language
4-year project funded by the Heising-Simons Foundation

- Develop, pilot, evaluate, and disseminate a family-centered picture book intervention

**FOUR PHASE INTERVENTION DEVELOPMENT**

- 2016-2017: Book Development
- 2018-2019: Evaluation of Intervention Effects through two RCTS
- 2019-2020: Dissemination
PHASE 1 – BOOK DEVELOPMENT

- 4-year project funded by the Heising-Simons Foundation
  - **Develop**, pilot, evaluate, and disseminate a family-centered picture book intervention

2016-2017
Book Development

2017-2018
Piloting of Intervention and Development of Training Materials

2018-2019
Evaluation of Intervention Effects through two RCTS

2019-2020
Dissemination
PHASE 1 – BOOK DEVELOPMENT

- Four key components to the book development process:
  - Empirically grounded book design
PHASE 1 – BOOK DEVELOPMENT

- Design of books – both a science and an art
  - Professional illustrator and author
REASONS FOR A PROFESSIONAL ILLUSTRATOR
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REASONS FOR A PROFESSIONAL AUTHOR

- The story writing process is phenomenally complex
  - Characters must have depth, but stay consistent across stories
  - There must be an engaging story arc (both internal and external)
  - Page turns...the story needs to draw families in to turn the page
  - Language must be appropriate for target age
REASONS FOR A PROFESSIONAL AUTHOR

- Attention to industry standards
  - Typically 32 total pages including cover and back (~12 spreads)
  - Text length: ~250-350 words for preschool age books
    - Every word counts!
    - Harder to write than we would expect
  - Not attending to these issues may limit distribution of books eventually or increase costs
PHASE 1 – BOOK DEVELOPMENT

- Design of books – both a science and an art
  - Professional illustrator and author
  - Text on one page, picture on other page (Flack & Horst, 2018)
Let little, if I throw
This fair blossom down to you,
Would you catch it as you stand,
Holding up each tiny hand,
Looking out of those grey eyes,
Where such deep, deep wonder lies?

Ttie finest, biggest fish, you see,
Will be the trout that's caught by me;
But if the monster will not cry,
Why, then I'll look a little nite.
Benjamin carefully measured the milk. They had just enough to match the recipe.

"Yay!" Lucy cheered.

CRACK

Some of the eggs were broken.

"Oops!" said Lucy. "Now there are not enough eggs."

1. Why aren't there enough eggs?
2. Do they have more cups of sugar or more cups of milk?
3. Now they have a different number of eggs as the recipe. How can they have the same amount?
Design of books – both a science and an art

- Professional illustrator and author

- Text on one page, picture on other page (Flack & Horst, 2018)

- Illustrations provided opportunities for counting, comparing, adding, etc.
  - Clear countable sets to avoid counting confusion (Ward et al., 2017)
CLEAR COUNTABLE SETS

- Ward et al., 2017

5 apples | 5 apples | 5 apples
CLEAR COUNTABLE SETS
CLEAR COUNTABLE SETS
PHASE 1 – BOOK DEVELOPMENT

- Four key components to the book development process:

  - Empirically grounded book design
  - Developed in English and Spanish
According to the U.S. Census Bureau (2017), there are over 40 million individuals over the age of 5 who speak Spanish at home in the U.S.
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- Quality of books and translation is often less than ideal

- Cost is higher than the same book in English
The Very Hungry Caterpillar
by Eric Carle | Mar 23, 1994
⭐⭐⭐⭐⭐ ~ 3,853
Board book
$5.91
✔ prime Get it as soon as Sun, Nov 17
FREE Shipping on orders over $25 shipped by Amazon
More Buying Choices
$1.00  (248 used & new offers)
Audible Audiobook
$0.00 $7.99
Free with Audible trial
Kindle
$9.99 $10.99
Other formats: Hardcover, Audio CD,

La oruga muy hambrienta/The Very Hungry Caterpillar: bilingual board book
by Eric Carle | May 12, 2011
⭐⭐⭐⭐⭐ 119
Board book
$8.66 $10.99
✔ prime Get it as soon as Sun, Nov 17
FREE Shipping on orders over $25 shipped by Amazon
More Buying Choices
$2.33  (66 used & new offers)
Development in English and Spanish

- Dialect neutral
- Gendered language
- Word difficulty/language differences
CHALLENGES IN TRANSLATION

- Spanish
  - Most
  - La mayoría, la más
PHASE 1 – BOOK DEVELOPMENT

- Four key components to the book development process:
  - Empirically grounded book design
  - Developed in English and Spanish
  - Math language integrated into pictures and text
PHASE 1 – BOOK DEVELOPMENT

Book 1: Greater

Too Many Pillows

Written by Angela M. Isaacs
Illustrated by Matt Cye

Book 2: Equivalence

Just Enough Eggs

Written by Angela M. Isaacs
Illustrated by Matt Cye

Book 3: Fewer

Picnic with Some Peanuts

Written by Angela M. Isaacs
Illustrated by Matt Cye
Use of dialogic reading prompts (Arnold & Whitehurst, 1994; Lonigan et al., 1999)

- Empirically grounded book design
- Developed in English and Spanish
- Math language integrated into pictures and text
- Built-in Prompts
"I packed a lot of pillows," Benjamin said. "I don't want the ground to be hard."

"Bear and I packed pillows too!" said Lucy.

Bear had a pillow. Lucy had more pillows. Benjamin had the most pillows.

1. Who has more pillows: Bear or Benjamin?

2. Benjamin likes to sleep with a lot of pillows. What do you like to sleep with?

3. Why doesn’t Bear need as many pillows as Lucy or Benjamin?
RESULTS

Additional Parent-Spoken Prompts and Child Questions by Condition

- Adult Prompts
- Child Questions

** ns

No DR DR
4-year project funded by the Heising-Simons Foundation

- Develop, **pilot**, evaluate, and disseminate a family-centered picture book intervention

- Obtaining **systematic** and **direct feedback** from a diverse group of parents

**FRAMEWORK FOR NEW INTERVENTION**

- **2016-2017**: Book Development
- **2017-2018**: Piloting of Intervention and Development of Training Materials
- **2018-2019**: Evaluation of Intervention Effects through two RCTS
- **2019-2020**: Dissemination
Phase 2a – Book Refinement
- Single-visit reading of books to obtain feedback on the books and dialogic reading prompts

Phase 2b – Intervention Refinement
- Full implementation of intervention with families to obtain feedback on the intervention process and evaluate differences in instructional intensity.
Goal: Obtain initial feedback on the design and development of the books.
10 total parent-child dyads
- Five monolingual English speakers
- Five bilingual/monolingual Spanish speakers
PHASE 2A – BOOK REFINEMENT

- 10 total parent-child dyads
  - Five monolingual English speakers
  - Five bilingual/monolingual Spanish speakers

- Key points of positive feedback from parents:
  - Text-picture match
  - Books held attention
  - Questions helped with storyline and engagement
  - Books were highly enjoyable for parent (8.5/10) and child (8.2/10)
Key constructive feedback from parents:

- Refinement of text and questions
- Improved instructions page
- Particular types of examples parents would benefit from seeing in training
- Bilingual versions of books rather than Spanish versions
“¡Oh no!” lloró Lucy. “El pastel está arruinado.”
“Está bien,” dijo Benjamín. “Podemos hacer otro pastel juntos.”

1. ¿Por qué está arruinado el pastel?
2. ¿Qué pasará cuando Lucy y Benjamín hagan otro pastel?
3. ¿Qué se le olvidó a Lucy ponerle al pastel?

“¡Oh no!” Lucy cried. “The cake is ruined.”
“It’s alright,” said Benjamin. “We can bake another cake together.”

1. Why is the cake ruined?
2. What will happen when Lucy and Benjamin bake another cake?
3. What did Lucy forget to put in the cake?
PHASE 2B – INTERVENTION REFINEMENT

- Goal: Obtain feedback from parents on the intervention process including fidelity, growth in knowledge, and feasibility.
  - Also test the level of parent training intensity needed to generate positive growth on outcome variables.
PHASE 2B – INTERVENTION REFINEMENT

Random Assignment

Pretest
Math
Math Language
Vocabulary

Minimal Training
Single instruction page on how to use the dialogic reading prompts

More In-depth Training
Training video plus single instruction page

Intervention
4 weeks
3 readings/week
15-20 min/reading

Posttest
Math
Math Language
Vocabulary
Attention Readers!

Kids learn more and have more fun when they get involved in story time. Make reading a conversation with your children! Here are some tips:

1. Ask one question per page.
   - Red questions for 1st reading
   - Blue questions for 2nd reading
   - Purple questions for 3rd reading
   - After the third reading, use any question or make up your own!

2. Keep the conversation going.
   Be flexible! Build on what your child says and relate the conversation to his or her interests.

3. Have fun!
PHASE 2B - INTERVENTION PROCESS

Your timeline for participation

Visit Hanley Hall: 1202 W. State St. Meet with researchers for an hour, so we can learn more about you and get you ready to read!

First week
Read Too Many Pillows to your child three times this week.

Second week
Read Just Enough Eggs to your child three times this week.

Third week
Read Picnic with Some Peanuts to your child three times this week.

Fourth week
Read each book one time this week.

Visit Hanley Hall: 1202 W. State St. Meet with researchers for an hour, so we can find out how it went!

You will get two weekly reminders about your readings, and we will check in with you at the end of each week with a brief survey!
PHASE 2B – PILOT FINDINGS

- Multi-method fidelity collection
  - Weekly Qualtrics surveys and audio recording of sessions using a USB audio recorder.
  - Total number of readings
    - Parents reported completing, on average, 10.5/12 readings
    - 56% of parents reported completing all 12 readings
    - 81% of parents reported completing at least 10 readings
Multi-method fidelity collection

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- Total number of readings
  - Parents reported completing, on average, 10.5/12 readings
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  - 81% of parents reported completing at least 10 readings

- Using Dialogic reading prompts
  - 94% of the time parents reported reading all or most of the designated questions
  - 64% of the time parents reported reading more than just the designated question at least for some pages
PHASE 2B – PILOT FINDINGS

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- Engagement/Enjoyment
  - On a scale of 1 (lowest) to 10 (highest) parents reported that their children highly enjoyed reading the books (8.5/10)
    - Enjoyment level was consistent across all four weeks (8.6, 8.6, 8.3, 8.5)
Improvement in Math Language and Numeracy

- Math Language
  - Normative Monthly Growth
  - Low Intensity
  - Higher Intensity

- Numeracy
  - Purpura et al., 2017 Intervention

Purpura et al., 2017 Intervention

Improvement in Math Language and Numeracy
**PILOT INTERVENTION EFFECTS**

Improvement in Math Language and Numeracy

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  - Higher Intensity

- **Numeracy**
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PILOT INTERVENTION EFFECTS

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- Numeracy

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- Higher Intensity

Purpura et al., 2017 Intervention
PILOT INTERVENTION EFFECTS

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- Numeracy
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  - Higher Intensity
  - Purpura et al., 2017 Intervention
Brief training is needed to generate effects on math language, but may not be necessary to improve numeracy.

Multi-method fidelity collection resulted in more complete fidelity data than either alone.

Parent feedback in the development process is extremely useful.
• 4-year project funded by the Heising-Simons Foundation
  • Develop, pilot, evaluate, and disseminate a family-centered picture book intervention

2016-2017
Book Development

2017-2018
Piloting of Intervention and Development of Training Materials

2018-2019
Evaluation of Intervention Effects through two RCTs

2019-2020
Dissemination
PART 3

- Randomized Control Trial to evaluate the effects of the intervention on children’s math language and numeracy skills.
INTERVENTION MATERIALS

- Quantitative Language Books

Book 1: Greater

Book 2: Equivalence

Book 3: Fewer
ACTIVE CONTROL MATERIALS

- Comparison books
  - Do not contain quantitative or spatial language

- Somewhat cover topics of bike safety, bedtime routine, and sharing

- Illustrations originally from the Narrative Assessment Protocol developed at Michigan State University (Ryan Bowles)
INTERVENTION PROCESS

Random Assignment

Pretest
Numeracy
Math Language
Vocabulary
Attentional Flexibility

Active Control
Comparison Books

Math Language Intervention
Little Elephants' Big Adventures Series

Intervention
4 weeks
3 readings/week
15-20 min/reading

Posttest
Numeracy
Math Language
Vocabulary
Attentional Flexibility

8 week Delayed Posttest
Numeracy
Math Language
Vocabulary
Attentional Flexibility
PARTICIPANTS

84 participating families

- Adults: 75 mothers, 5 fathers, 3 grandparents, 1 others
  - Median education, Bachelor's degree

- Children:
  - 3.03 to 5.31 years old ($M = 4.14$, $SD = 0.61$)
  - 40 female, 44 male
  - 76.1% Caucasian, 1.2% Hispanic, 4.8% African American, 2.4% Asian, 14.3% multi-racial, 1.2% did not report
Preliminary Analyses

- **Attrition**
  - 6 families did not attend visit 2
  - 4 families did not attend visit 3

- **Dosage**
  - On average, parents reported reading to their children for 10.69 sessions (out of 12)
    - 81% of families in the intervention group read at least 10 times
    - 74% of families in the control group read at least 10 times

- **Child Enjoyment**
  - Parents reported that their children really enjoyed the books (~8.5/10)
Four regression analyses

- Math language: posttest, delayed posttest
- Numeracy: posttest, delayed posttest

Covariates
- Pretest scores on: math language, numeracy, vocabulary, attentional flexibility, sex, age, parent education, and dosage
**INTERVENTION EFFECTS – MATH LANGUAGE**

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Posttest</th>
<th>Delayed Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intervention</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Active Control</strong></td>
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</tbody>
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*** d = .50

+ d = .25

*** p < .001 d = .22, * p < .05, + p < .10
**INTERVENTION EFFECTS - NUMERACY**

* d = .22

* d = .23

*** p < .001 d = .22, * p < .05, + p < .10
Were the intervention effects different depending on:

- Initial math language
- Initial numeracy
- Age
- Parental education
- Dosage
- Sex
Were the intervention effects different depending on:

- Initial math language ✗
- Initial numeracy ✗
- Age ✗
- Parental education ✗
- Dosage ✗
- Sex ✗
Were the intervention effects different depending on:

- Initial math language ✗
- Initial numeracy ✗
- Age ✗
- Parental education ✗
- Dosage ✗
- Sex ✗
- Parent math anxiety
Were the intervention effects different depending on:

- Initial math language ❌
- Initial numeracy ❌
- Age ❌
- Parental education ❌
- Dosage ❌
- Sex ❌
- Parent math anxiety ❌
CONCLUSIONS

- The brief intervention has immediate effects at posttest on both math language and numeracy skills; however, the effects on math language decrease, but are still practically important 8 weeks later.

- Effects were not dependent on a range of possible moderators.

- Parents exhibited high levels of implementation fidelity (dosage).

- This was an easy to use process for parents and their children enjoyed it.
NEXT STEPS

- Examine audio recordings to measure implementation fidelity
  - Engagement, use of dialogic reading prompts, parent and child use of numeracy, etc.
- Finish other RCT with Spanish-English dual language learners
- Finish development of spatial language books and patterning books
- Expand the series of books to include a broader range of math foci
- Explore additional tools (e.g., e-books, animated shorts) for supporting learning
- Dissemination of materials to parents and schools
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QUESTIONS?

David J. Purpura
@davidjpurpura; @pearl_center
purpura@purdue.edu
Associate Professor
HDFS, Purdue University